Radiological Worker Training

Study Guide

ESH713
Radiological Worker Training for X-ray Users
Modules 1–5, plus Lessons Learned

ESH700
Radiological Worker Training Level I
Modules 1–7, 10 plus Lessons Learned

ESH701
High Radiological Worker Training
Modules 1–8, 10 plus Lessons Learned

ESH702
Radiological Worker Training Level II
Modules 1–10 plus Lessons Learned

Table of Contents

MODULE 1 – RADIOLOGICAL FUNDAMENTALS

Module Objectives

This module begins with basic nuclear science topics and then introduces you to radiological fundamentals and terms that are commonly used at Argonne.

Upon completion of this module, you will be able to:

- Identify the three basic particles of an atom.
- Define radioactive material, radioactivity, radioactive half-life, and radioactive contamination.
- Identify the units used to measure radioactivity and contamination.
- Define ionization and ionizing radiation.
- Distinguish between ionizing and non-ionizing radiation.
- Identify the four basic types of ionizing radiation and their physical characteristics, range, shielding, biological hazards(s), sources at the site.
- Identify the units used to measure radiation.
- Convert rem to millirem and millirem to rem.

Three Basic Particles of the Atom

All matter is composed of atoms. Atoms are made up of three basic particles: protons, neutrons, and electrons.

Protons and neutrons are in the center of the atom, called the nucleus. Electrons can be thought of as circling the nucleus, as the planets orbit the sun. Protons have a positive electrical charge. Neutrons have no electrical charge. The number of neutrons influences atomic stability. Electrons have a negative electrical charge.

Atoms Can Emit Radiation

An atom's stability is determined by the ratio of protons to neutrons in the nucleus. An atom is unstable when there are too many or too few neutrons, relative to the number of protons. Unstable atoms will go to a more stable condition by getting rid of excess energy from the nucleus of the atom. This excess energy is expelled by emitting radiation (i.e. energetic particles or waves) that carries the energy away. This process is known as radioactive decay. A distinct result of radioactive decay is that the amount of radioactivity occurring will diminish over time as more and more atoms undergo the decay process, eventually becoming stable.

Radioactivity: the process of unstable atoms emitting radiation in the form of energetic particles or waves to become stable. This process over time is referred to as radioactive decay.

Disintegration: a single atom undergoing radioactive decay.

Radioactive Half-life

The half-life is the time it takes for half of the radioactive atoms in a material to decay. This may occur in a fraction of a second or over millions of years.

Radioactive Materials

Radioactive material is any material containing unstable atoms that emit ionizing radiation. Recall that the atoms are unstable because their ratio of neutrons to protons is too high or too low. Radioactive material can be manmade or naturally occurring, and can be in any of these physical forms:

- Solid
- Liquid
- Gas
- Dust
- Powder

Radioactive Contamination

When radioactive material is uncontained and in a place where it is not supposed to be, it is known as radioactive contamination.

Fixed contamination is radioactive contamination that is firmly affixed to, or imbedded in, a surface and cannot be removed without damaging the surface.

Dispersible contamination (a.k.a. loose or smearable) is radioactive contamination that is readily removed, even by casual contact or ambient air flow. Note that dispersible contamination can even become airborne.

Two main concerns with radioactive contamination are:

- Spreading it to unwanted locations
- Having it enter the body

Radioactive Material and Radioactive Contamination

Let’s compare radiation, radioactive material, and radioactive contamination to fire.

When logs burn, they give off heat. This is a form of radiation. We know that radioactive material emits energy in the form of particles or waves. The burning material is similar to radioactive material as they both release energy through space.

The sparks can jump and spread the fire to areas where they are not desired. This can be compared to radioactive contamination.

Units Used to Measure for Radioactivity

Radioactivity is measured in the number of disintegrations (decays) radioactive material undergoes in a certain period of time. The units of measure for radioactivity include:

- Disintegrations per minute (dpm)
- Disintegrations per second (dps)
- Curie (Ci) - named in honor of Pierre and Marie Curie who originated the term radioactivity. This unit is equal to the radioactivity of 1 gram of Ra-226, which is 37 billion dps. The curie is used to describe the total quantity of radioactive material present. One curie is defined as: 2,200,000,000,000 disintegrations per minute (2.2 x 1012 dpm) or 37,000,000,000 disintegrations per second (3.7 x 1010 dps).
- Becquerel (Bq) - named in honor of Henri Becquerel who shared a Nobel Prize with Pierre and Marie Curie for their work with radioactivity. This unit is equal to one dps.

Units Used to Measure Radioactive Contamination

Radioactive contamination is measured in units of radioactivity per unit of surface value, or within a volume or mass. See below for examples of contamination measurement units.

Flat Surface Area Measurement

- Contamination detector placed over a contaminated area displays 500 dpm
- Probe open surface area = 100 square centimeters (cm^2)
- Measurement Unit = 500 dpm/100 cm^2

Volume

- Contamination detector measurement of the liquid displays dpm
- Contaminated liquid displays in milliliters (ml)
- Measurement unit displays = dpm/ml

Mass

- Contamination detector measurement of the solid displays dpm
- Contaminated solid measured in grams (g)
- Measurement unit = dpm/g

Ionization and Ionizing Radiation

Ionization is the process of removing electrons from atoms. When an electron is removed from an atom, the result is a positively charged atom and negatively charged particle (electron); subsequently, an ion can be defined as an electrically charged atom or particle (i.e. the ionized atom or a freed electron).

If radiation has enough energy to remove electrons from atoms, it is called ionizing radiation. The ionized atom is then called an ion. Once the freed electron attaches to another atom, this atom is also considered an ion because it now has a negative charge.

Non-Ionizing Radiation

Non-ionizing radiation: radiation which lacks the energy to remove electrons from atoms.

Examples of non-ionizing radiation are visible light, radio waves, microwaves, and magnetic fields.

Four Types of Ionizing Radiation

Most radiological work will expose workers to at least one of the four basic types of ionizing radiation.
These are alpha particles, neutron particles, beta particles, and photons (gamma rays and X-rays).

The radiation originates in the nucleus, with the exception of X-rays, which are produced in the electron orbitals.

You will learn more about each type of ionizing radiation by reviewing:

- Its characteristics
- What type of penetration range it has
- The hazards the radiation presents to the body

You will also become aware of the common sources found here at Argonne.

Four basic types of ionizing radiation of concern are:

- Alpha particles (α)
- Neutron particles (η)
- Beta particles (β)
- Photons (gamma rays (γ) and X-rays)

Types of Ionizing Radiation: Alpha Particles

Characteristics

- Contain a strong 2+ charge
- Strip electrons from nearby atoms as they pass
- Cause ionization

Range

- Deposit large amounts of energy in a short path
- Limited penetrating ability – very short range
- Range in air is 1”- 2” (depending on the energy)

Shielding

- Stopped by a few centimeters of air
- Sheet of paper or outer layer (dead layer) of skin

Hazards

- Little to no external hazard as alpha particles are generally easily stopped
  Only high energy (≥ 7.5 MeV) alpha particles can penetrate the dead layer of skin
- Large internal hazard if inhaled or digested when the source of alpha radiation is in close contact with living cells
- Can deposit large amounts of energy in small volume of body tissue

Sources

Examples of alpha-emitting sources at Argonne include:

- Americium: (Am-241)
- Uranium: (U-238, U-nat, Depleted U)
- Plutonium: (Pu-238, Pu-239)
- Radium: (Ra-226)
- Radon: (Rn-220)
- Thorium: (Th-230, Th-232)

All of these, as well as numerous other transuranic alpha emitting isotopes (i.e. nuclides coming after Uranium on the periodic table which have more protons in their nucleus), may be found at Argonne.

Types of Ionizing Radiation: Beta Particles

Characteristics

- Small mass (7,000 times less mass than alpha particles)
- -1 charge or +1 charge (positron)
- Identical in mass to electrons
- Originates from the nucleus

Range

- Range depends on the energy of the beta particle and the material involved
- Limited penetrating ability- short distance (1” to 20’)
- Range in air is about 12 feet per MeV of energy

Table 1: Range of Ionizing Radiation

Radioisotope	Maximum Energy (MeV)	Range in air
Tritium (H-3)	0.018	¼ inch
Sulfur-35	0.167	1 inch
Phosphorus-32	1.71	20 feet

Shielding

- ¼” thickness of plastic or glass
- Safety glasses

Note: Although thin metal foil will stop most betas, it may cause the undesired generation of bremsstrahlung X-rays which can penetrate the thin foil.

Hazards

- External hazard to skin and eyes
- Internal hazard if inhaled or ingested; causes much less ionization damage than alpha particles

Sources

Examples of beta-emitting sources at Argonne include:

Sealed radioactive “check” sources:

- Strontium: (Sr-90)
- Technetium: (Tc-99)

Radioisotopes used in biology/chemistry/medical research:

- Tritium: (H-3)
- Carbon: (C-14)
- Phosphorus: (P-32, P-33)
- Molybdenum: (Mo-99)
- Iodine: (I-129, I-131)

Fission products from nuclear reactions:

- Cesium: (Cs-137)
- Strontium: (Sr-90)

Activation products from nuclear reactor or accelerator facilities:

- Tritium: (H-3)
- Calcium: (Ca-45)
- Manganese: (Mn-54)
- Cobalt: (Co-55, Co-56, Co-60)

Types of Ionizing Radiation: Gamma/X-Rays (Photons)

Characteristics

- No charge
- No mass
- Similar to visible light
- Gamma rays originate within the nucleus
- X-rays are released by bremsstrahlung radiation or when electrons drop to a lower orbit
- Both gamma and X-rays can ionize as a result of direct interactions with orbital electrons

Range

- Range in air is very far
- May easily go several hundred feet

- Very high penetrating ability since it has no mass and no charge

Shielding

- Lead
- Steel
- Concrete

Hazards

Whole-body exposure

- External sources of gamma/X-ray radiation can penetrate deep into the body affecting all organs
- Internal hazard as it can deliver a constant radiation dose to whole body until excreted

Sources

- X-ray diffraction units
- Electron microscopes
- Radionuclides in hot labs
- Irradiators and radiography devices
- Accelerators (while operating and residual activation products)
- Sealed radioactive sources used for calibration/checks

There are no longer any operable nuclear reactors at Argonne. However, all of the common sources may be found at Argonne.

Types of Ionizing Radiation: Neutrons

Characteristics

- No electrical charge in nucleus (neutral)
- Ejected from the nucleus after interaction
- May interact with matter directly or indirectly
- Neutron/nucleus collisions may cause indirect ionization

Range

- Similar to gamma/X-rays, range in air is very far
- Can easily go several hundred feet

Shielding

Best shielded by materials with a high hydrogen content

- Water
- Plastic
- Concrete

Hazards

- Whole-body exposure – high penetrating ability
- Generally an external hazard

Sources

- Operating power reactors (none at Argonne currently)
- Operating particle accelerators
  - ATLAS
  - APS
- Manufactured (sealed) sources – PuBe, AmBe, RaBe, Cf-252 (californium) sources typically used to calibrate neutron detection instruments
  - Fissile nuclear materials
  - U-235
  - Pu-239 releases very small numbers of neutrons
  - Nuclear criticality accidents

Units Used to Measure Radiation

Radiation Absorbed Dose (rad)

- Radiation Absorbed Dose, or rad, is a unit for measuring an absorbed dose in any material and applies to all types of radiation.
- Rad does not take into account the potential effect that different types of radiation have on the body.
- 1 rad = 1,000 millirad (mrad)

Roentgen (R)

- Measures ions collected from air exposed to gamma rays or X-rays.
- Does not relate biological effects of radiation on the human body.
- 1 roentgen = 1,000 mR
- Named after Wilhelm Roentgen who discovered X-rays in 1895.

Roentgen Equivalent Man (rem)

- Roentgen equivalent man (rem) is a unit for measuring equivalent dose.
  Equivalent dose takes into account the biological effect on the body caused by the energy absorbed (dose) and from the different types of radiation. It is the most commonly used unit.
- Different radiation types cause different levels of biological damage even though the absorbed dose may be the same. The rem unit takes this into account.
- 1 rem = 1,000 millirem (mrem).

Converting rem to millirem

All of the radiation units of measure are recorded in units and subunits. It's important to be able to convert the units to subunits and, conversely, the subunits to units.

- 1 R = 1,000 mR
- 1 rad = 1,000 mrad
- 1 rem = 1,000 millirem

When using a very small unit, let's say a "byte" (B) in the computer world, we would want to express a file size not in bytes, but a multiplier of bytes. This conversion is done by moving the decimal, usually three spaces at a time. So, the file size of a simple letter would be about 10,000 bytes or 10 kilobytes since:

- 1,000 bytes = 1 kilobyte

The opposite is true with radiation exposure, as the units of rad and rem are very large and we want to express them in terms that are smaller than the original unit. We will use the rem as an example.

- When converting to rem, move the decimal to the left.
- When converting to millirem, move it to the right.

Radiation Weighting Factor

Recall that each type of radiation differs in its ability to cause biological harm. A radiation weighting factor (RWF) is used as a multiplier to account for the relative amount of biological damage caused by the same amount of energy deposited in cells by the different types of ionizing radiation.

Alpha radiation ionizes a lot of atoms in a very short distance and is more damaging than beta or gamma radiation for the same amount of energy deposited.

A multiplier shows the amount of biological damage caused by the same amount of energy.

- rem = rad x RWF

Prior to 2007, the radiation weighting factor was known as a quality factor (QF).

Radiation Dose and Dose Rate

Radiation level in terms of dose rate at one foot from a radiation source is used to designate the level of radiation hazard in the area. This is what is used to designate an area as a Radiation Area (5 millirem/hour at one foot), or high radiation area (100 millirem/hour at one foot).

The dose rate is usually recorded in millirem/hr.
One foot = 30 centimeters (cm), which you may see in radiation safety documentation, such as radiological work permits or work control documents.

- Dose: the amount of radiation received
- Dose rate: the amount of radiation received divided by the length of time over which the radiation is received
- Radiation level, or intensity, in an area: millirem/hr

MODULE 2 – BIOLOGICAL EFFECTS

Module Objectives

We have known about the biological effects of ionizing radiation for a number of years and have gained further information of these effects since World War II. In this module, we will explore the potential effects and risks of ionizing radiation. By analyzing the risk associated with radiological work, you will gain perspective about the level of occupational risk when compared to other health risks.

Upon completion of this module, you will be able to:

- Identify the major sources of natural background and man-made radiation.
- Identify the average annual dose to the general population from natural background and manmade sources of radiation.
- State the method by which radiation causes damage to cells.
- Identify the possible effects of radiation on cells.
- Define the terms “acute dose” and “chronic dose”.
- State examples of chronic radiation dose.
- Define the terms “somatic effect” and “heritable effect”.
- State the potential effects associated with prenatal radiation dose.
- Compare the biological risks from chronic radiation dose to health risks that workers are subjected to in industry and daily life.

Introduction

If asked the following questions, how would you respond?

How much radiation do you receive each year?
Where does the exposure come from?
What is the average dose of radiation a person receives in a year?

We live in a radioactive world and always have. We are exposed to ionizing radiation from natural sources and man-made sources. The dose of radiation received from natural sources is normally greater than from our jobs. In this section, we will discuss the average exposure of the U.S. population to ionizing radiation from background sources:

- Ubiquitous natural sources of background radiation
- Medical exposure to patients
- Consumer products and daily activities

Natural Sources of Background Radiation

There are four natural sources of background radiation, meaning radiation that is always around us. These are:

- Cosmic radiation

- Sources in the earth's crust (terrestrial)
    - Radium
    - Uranium
    - Thorium
    - Potassium
- Internal sources in the human body
- Radon

The first natural source, cosmic radiation, originates from the sun, stars, and other sources in outer space. These particles are going through the probe and causing the monitor to count. Cosmic radiation consists of positively charged particles and gamma radiation.

In Denver, Colorado, there would be twice the cosmic radiation dose rate compared to that at sea level. That is because the atmosphere shielding decreases at higher altitudes. Cosmic radiation results in a dose rate of approximately 35 mrem/yr.

Natural elements found in the earth such as soil and rocks can also be detected. These include trace amounts of radium, uranium, thorium, and potassium. As the elements decay, they give off a continuous low level of radiation. Terrestrial radiation results in a dose rate of approximately 20 mrem/yr.

The third natural source of radiation is the internal sources in the human body. These come from the food we eat and the water we drink as they contain natural radioactive materials. These materials deposit in our bodies and cause internal exposure to radiation. Most of our internal dose comes from a radioactive form of potassium called K-40. Internal sources of radiation give us a dose rate of approximately 30 mrem/yr.

Radon is the fourth source of radiation and comes from the decay of radium. It is naturally present in the soil and takes the form of gas. It can travel through the soil and enter buildings through foundation cracks. Radon emits alpha radiation, which is an internal hazard to the lungs. The inhalation of radon gas results in a dose rate of approximately 230 mrem/yr.

Man-Made Sources of Radiation

The difference between natural background sources and man-made sources of radiation is the origin of the source; that is, where the radiation is either produced or enhanced by humans. The four top sources of man-made radiation are:

- Medical radiation = 300 mrem/yr
- Cigarette smoking = 1,300 mrem/yr
- Building materials = 4 mrem/yr
- Commercial air travel = 3 mrem/yr

Note, these dose rate numbers consist of a statistical average of all members of the public living in North America. Of course, if you don't smoke or have not had medical CT scans or nuclear medicine tests or therapies, or don't take long plane trips, then your individual background radiation dose would be greatly reduced.

The average yearly dose to the public due to natural background radiation and man-made sources is approximately 620 mrem.

Effects of Radiation on Cells

The human body is composed of a collection of organ systems. Each organ system consists of tissues, and tissues are made up of specialized cells. Every cell contains millions of atoms.

Ionizing radiation is how radiation damage occurs in the human body. Any potential radiation damage to the body begins with damage to the atoms. Radiation causes damage to human cells by ionizing the atoms.

A cell is made up of two main parts, the body of the cell and the nucleus. The nucleus is like the brain of the cell. When ionizing radiation hits a cell, it may strike a vital part of the cell, like the nucleus, or a less vital part, like the cytoplasm.

Cell Sensitivity

Some cells in our body are more sensitive to ionizing radiation because they are actively dividing cells. These include:

- Blood-forming cells
- Cells that line our digestive tract
- Hair follicles
- Cells that form sperm

Slower dividing cells are less sensitive to ionizing radiation

- Brain cells
- Muscle cells

Possible Effects of Radiation on Cells

Cells damaged and operate abnormally:

- May not be able to function properly
- If a chromosome is damaged but not repaired correctly, cell may continue to reproduce (mutate) and may result in cancer

Cells damaged but repair and operate normally:

- Ionizing radiation can interact with water in a cell creating hydrogen peroxide as a byproduct
- Ionizing radiation may hit nucleus and cause a change in chromosome
- Body can repair damage to chromosome and cell structure

Cells die:

- Radiation damage to cell may cause premature death
- Body naturally replaces dead cells
- Dead cells do not pose a future cancer risk
- May cause health problems

No Damage:

- Radiation passes through a cell without causing any iodization or damage

Acute and Chronic Radiation Dose

Potential biological effects depend on how much and how fast a radiation dose is received. Acute radiation doses are large doses of radiation received in a short period of time such as dose received during large scale accidents.

Chronic radiation doses are small amounts of radiation received over long periods of time such as dose received by radiation workers, and dose from background radiation.

After an Acute Dose to the Body

After an acute dose, the body will try to repair itself as damaged cells begin to be replaced by new cells. This process may take months. Only in extreme cases, such as the Chernobyl firefighters, would a dose be so high (500-800 rem) that recovery would be unlikely even with intensive medical care.

There have been accidents, particularly with X-ray machines, where individuals have exposed their fingers to an intense radiation beam. In some cases, individuals received millions of mrem to their fingers, and some have even lost a finger or fingers.

Chronic Radiation Doses and Biological Effects

There are two terms used to distinguish the biological effects of chronic radiation doses:

Somatic effect
A somatic effect refers to the effects radiation has on the individual who received the dose. The somatic effects are classified as either prompt or delayed effects.

Prompt effects
Radiation sickness and radiation burns seen immediately after large doses of radiation delivered over a short period of time.

Delayed effects
Cataract formation and cancer induction that may appear months or years after a radiation exposure.

Heritable effect
A genetic effect refers to mutations or changes due to radiation damage to the DNA.

A heritable effect refers to the damage of the parent's reproductive cells which was passed on to the children.

Heritable effects of radiation have been observed in controlled experiments with plants and animals but have never been observed in humans. This includes studies of 77,000 Japanese children born to survivors of atom bombs. The risk of your future children receiving a heritable effect due to your occupational radiation exposure is very small.

Biological Damage Factors

There are a number of factors that determine the biological damage due to radiation exposure.

Total Dose: The greater the dose, the greater the potential for biological effects.

Dose Rate: The faster the dose is delivered, the less time the body has to repair it.

Type of radiation: Internally deposited alpha particles are more damaging than beta or gamma emitters.

Area of the body: The larger the area of the body that receives a dose, the greater the biological effect.

- Extremities are less sensitive than blood-forming and other critical organs. That is why the annual dose limit for extremities is higher than for a whole-body dose.

Cell Sensitivity: Rapidly-dividing cells are most sensitive such as:

- Blood-forming cells
- Cells that line our digestive tract
- Hair follicles
- Cells that form sperm

Individual Sensitivity:

- Developing embryo/fetus most sensitive
- Children more sensitive than adults
- Elderly people more sensitive than middle-aged people

Prenatal Radiation Exposure

Another type of somatic effect may occur if a fetus or embryo receives a radiation dose while in the mother's uterus.

The following have been observed when the fetus receives a dose of radiation:

- Lower birth weight

- Increased risk of intellectual disability
- Smaller physical size
- Lower IQ test scores and slower scholastic development
- Increased incidence of behavioral problems

Sensitivity of the fetus:

- More sensitive because cells are rapidly dividing
- Most susceptible if exposed at 8-15 weeks after conception

Many chemical and physical factors are suspected of causing or known to cause damage to a fetus, especially early in the pregnancy. These include:

- Radiation
- Alcohol consumption
- Exposure to lead
- Exposure to heat (e.g. hot tubs)

Conclusions about Occupational Radiation Risk

The top three risks listed below have the greatest effect on our overall health; yet these are simply lifestyle choices involved in general activities of daily life. These risk factors present the greatest impact on your life expectancy when you analyze the overall risks.

An occupational radiation dose is smaller, yet comparable to other routine occupational risks, and much less than some risks widely accepted in our society. To summarize, understanding radiation risk in comparison to other risks, in general, helps you develop an informed and healthy respect for radiation.

Table 2. Comparison of Health Risks

Health Risk	Estimated Loss of Life Expectancy
Smoking (20+ cigarettes/day)	6 years
Overweight (by 15%)	2 years
Alcohol consumption (U.S. average)	1 years
Agricultural Accidents	320 days
Construction Accidents	227 days
Auto Accidents	207 days
Home Accidents	74 days
Occupational radiation dose days	51 days
All natural hazards (earthquakes, lightning, flood)	7 days
Medical radiation	6 days

MODULE 3 – RADIATION LIMITS

Module Objectives

Earlier in this course, you became familiar with the occupational risk associated with radiological work. In this module, you will become familiar with the Department of Energy (DOE) and Argonne limits and administrative controls established for radiation dose and level of acceptable risk.

Upon completion of this module, you will be able to:

- State the purposes of the administrative control levels at Argonne.
- Identify the DOE radiation dose limits, DOE administrative control level and Argonne administrative control levels.
- State the Argonne policy concerning prenatal radiation exposure.
- Identify the employee's responsibility concerning radiation dose limits and administrative control levels.
- Identify the average annual radiation dose received by Argonne radiological workers.

Establishing Radiation Dose Limits

Radiation dose limits and administrative control levels have been established in order to keep occupational radiation exposures within acceptable levels.

The Department of Energy radiation dose limits are federal law, based upon guidance from national and international expert scientific groups and government agencies, such as:

- International Commission on Radiological Protection (ICRP)
- National Council on Radiation Protection and Measurements (NCRP)
- U.S. Environmental Protection Agency (EPA) Federal Law

Title 10 of the Code of Federal Regulations (10 CFR 835), "Occupational Radiation Protection," describes the protection standards and dose limits that apply to all DOE workers.

Administrative Control Levels

Beside the legal dose limits, both Department of Energy and Argonne have established administrative control levels for occupational radiation dose. These levels are set lower than the DOE's legal limit to ensure that workers do not exceed the DOE dose limits. Workers may not exceed the DOE administrative control level without prior approval from DOE. Workers may not exceed the Argonne administrative control level without prior approval from Argonne.

Setting lower limits than the DOE serves two purposes:

- Ensures the Department of Energy's limits are not exceeded
- Helps reduce individual and total worker population dose (collective dose)

Federal Law—DOE Dose Limit: Sets the radiation dose limits.
DOE Administrative Control Level: These levels are set lower than the DOE's legal limit**.**
Argonne Administrative Control Level: These levels are set lower than the DOE's Administrative Control Level.

DOE Radiation Dose Limit

The Department of Energy annual radiation dose limit applies to the sum of radiation doses received from two potential sources:

- External dose from radiation sources located outside the person's body.
- The committed internal dose from radioactivity deposited inside the body.

The sum of: External doses (effective dose) + Internal Doses (committed effective dose) = Total Effective Dose (TED)

Argonne's Administrative Control Level

Let's look at the Department of Energy dose limits and the Argonne administrative control level for the whole body.

The definition of the "whole body" covers the head, trunk, and most of the blood-producing and vital organs. It does not include the extremities (arms and hands below the elbow or the legs and feet below the knee); nor does it include the skin or the lens of the eye.

The Department of Energy's annual dose limit for the whole body is 5 rem per year. The Argonne administrative control level is 1 rem per year.

Dose Limits on Remaining Parts of the Body

Under certain circumstances, extremities may receive a higher radiation dose than the whole body. An example is when directly handling highly radioactive material. The extremities do not carry vital organs and are therefore less sensitive.If radioactive material enters the body, most of the radiation dose may be received by internal organs. DOE radiation dose limits exist for these and other special cases. Let's look at these limits and Argonne's administrative control levels.

Table 3: Radiation Dose Limit by Body Part

Body Part	DOE Annual Radiation Dose Limit	Argonne Administrative Control Level
Whole Body	5 rem/year	1 rem/year
Extremities	50 rem/year	N/A
Skin/Vital Organ*	50 rem/year	N/A
Lens of the Eye	15 rem/year	N/A
Child/Visitor	100 mrem/year	100 mrem/year

*This limit is for the committed dose to an organ or tissue, calculated over a 50-year period, following intake of radioactive material into the body.

Note: Extremities include the arms and hands below the elbow or the legs and feet below the knee.

Radiation Dose Limits and Pregnancy

DOE and Argonne want to minimize radiation exposure to the fetus/embryo. A pregnant worker or an individual who is planning to become pregnant and who is monitored for occupational radiation exposure may voluntarily declare their pregnancy in writing. Once the pregnancy is "declared", a more restrictive radiation dose limit of 500 mrem is applied over the gestation period. Argonne policy is to keep the fetal radiation dose as far below the 500 mrem limit as reasonably achievable.

The individual declaring pregnancy is required to fill out a Declaration of Pregnancy (ANL-943) form and send it to her supervisor. Once "declared," the worker should contact the Area Health Physicist for a consultation and work restriction determination (ANL-243). Work duty options are offered to reduce the risk of radiation exposure. Argonne employees should also consult with the Health and Employee Wellness Department in Building 201. This process is laid out in LMS-PROC-135.

Dose Limits and Your Responsibility

It is every worker's responsibility to comply with the Department of Energy's dose limits and Argonne's administrative control levels. The average annual dose to radiation workers at Argonne is approximately 150 mrem.

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

MODULE 4 – ALARA PROGRAM

Module Objectives

The Department of Energy (DOE) establishes dose limits and administrative control levels. Furthermore, Argonne sets an even more conservative administrative control level. In this module, we will explore how radiological workers and management do their best to keep radiation doses well below these limits by using the ALARA concept.

Upon completion of this module, you will be able to:

- State the ALARA concept.
- State the DOE/Argonne management policy for the ALARA program.
- Identify the responsibilities of management, Health Physics, and the radiological worker in the ALARA program.
- Identify methods for reducing external and internal radiation dose.
- State the pathways by which radioactive material can enter the body.
- Define methods for reducing internal radiation dose.
- Identify methods a radiological worker can use to minimize radioactive waste.

ALARA Program

ALARA stands for As Low As Reasonably Achievable. It is an approach to radiation safety that strives to prevent unnecessary exposures to the workforce and general public. The ALARA concept is an integral part of all activities that use radioactive materials and radiation generating devices at Argonne. It involves the reduction of both internal and external dose from ionizing radiation. The ALARA concept applies to all employees, visitors, the public, and the environment.

DOE Management Policy for the ALARA Program

The DOE ALARA Management program states that personal radiation dose will be maintained as low as reasonably achievable.

- Radiation doses are well below regulatory limits
- No radiation exposure without an overall benefit

Responsibilities for the ALARA Program

Implementing and using safe work practices that adhere to the ALARA principle are the responsibilities of Management, Health Physics and you, the radiological worker. The individual radiological worker is ultimately responsible for maintaining their radiation dose ALARA.

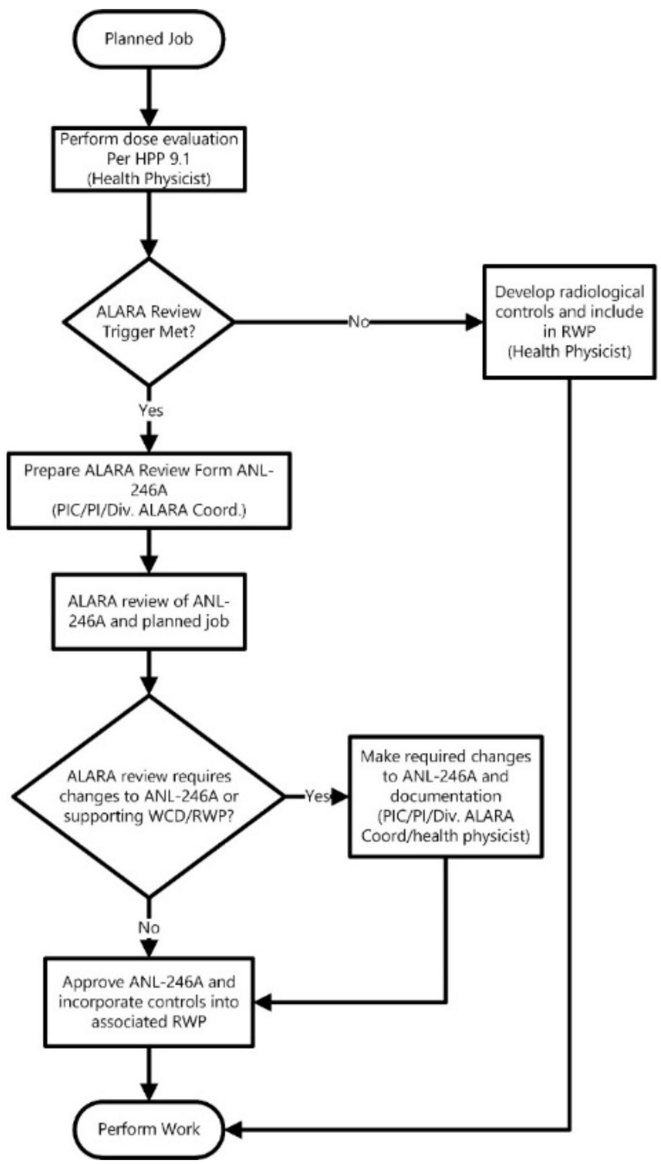
The ALARA Committee

The ALARA Committee sets ALARA goals for the lab. They work closely with the Lab Director on the effectiveness of the overall ALARA program and make recommendations to continuously improve it.

The primary function of the ALARA Committee is to review proposed projects submitted by the division that have significant radiological impact.

When the divisions plan radiological work, they must evaluate several radiological conditions. Divisions planning radiological work evaluate:

- Maximum dose rate
- Contamination levels
- Maximum individual worker dose
- Collective dose



For each of these criteria there are separate trigger levels. If any criteria are exceeded, then an ALARA review must also be performed. Work cannot begin until the ALARA Committee grants its approval.

Responsibilities of the ALARA Committee members

Argonne's Laboratory ALARA Coordinator:

- Appointed by Radiological Safety Officer (RSO)
- Provides technical support and ALARA program implementation support
- Serves as Secretary of the Argonne ALARA committee
- Provides quarterly reports tracking worker radiation doses

Argonne's Division ALARA Coordinators:

- Serve on the ALARA Committee
- Assist in setting up ALARA reviews for planned work for their division
- Support creation of division ALARA goals
- Provide feedback on how to improve the program

ALARA and Health Physics Responsibilities

Health Physics provides information on radiological conditions in the work area and assists in determining protective requirements. They can also help predict worker doses and advise on how to minimize the radiation doses by creating radiological work permits (RWPs) that implement the radiological protection program.

Health Physics ALARA Responsibilities:

- Provide information on radiological conditions in the work area
- Assist in determining protective requirements
- Predict worker doses and assist in minimizing radiation doses
- Create radiological work permits (RWPs) that implement the radiological protection program

ALARA and Management's Responsibility

Before any Health Physics or ALARA review activities can occur, the workers who perform these functions must be made aware of the planned radiological work. The best way to do this is to initiate a radiological work permit (RWP).

It is the responsibility of the job planner or supervisor to initiate a Work Planning and Control (WPC) document and forward it to Health Physics who will create an RWP for the work. Both the WPC document and RWP will be written with consideration to ALARA concepts throughout the work activity.

Additional information on the RWP is found in Module 6 and 10 of this course and in LMS-PROC-140.

ALARA and Workers' Responsibilities

Under the Price Anderson Amendments Act (PAAA), you have a responsibility to report to your supervisor any violations of the radiological safety rules. For example, if you saw that a coworker was eating, drinking, or smoking in a posted radiological area, or was not wearing a radiation dosimeter in an area where it was required, you would want to report that to your supervisor.

Worker radiological safety responsibilities include:

- Read all radiological postings and RWPs related to any part of your work
- Follow all specified radiological safety requirements (i.e. wearing protective clothing)
- Report to your supervisor any violations of the radiological safety rules (Price Anderson Amendments Act)

Reducing External Radiation Dose

The three basic protective measures used to minimize external dose include:

- Minimizing time
- Maximizing distance
- Incorporating shielding

Reducing time spent in the field of radiation will lower the dose received by workers. To minimize the time spent in the area, think of the work in two phases: planning and executing.

When planning the radiological work:

- Discuss the task thoroughly and pre-plan outside the radiological area. Plan to only use the number of workers actually required to complete the task.
- Gather all necessary tools and supplies so they are readily available.
- Conduct practice runs that duplicate the area prior to entering the area. This gives workers the confidence to perform the task efficiently and effectively when they do enter the area. Use mock-ups applicable to the work if available for practice runs.
- Consider decontamination before starting the job.

When executing the radiological work:

- Take the safest, most direct route to the work site.
- When possible, complete the work in areas with lower dose rates by moving the parts or components to those areas.
- Work efficiently, quickly, and accurately so that the task is completed the first time. Do not linger in high dose areas.
- Wait for short half-life materials to decay and do not linger in the area when finished.
- With the approval of Health Physics, remove any debris or waste when containers are full or waste starts to pile up.

Maximizing your distance is the second measure used to reduce your radiation dose. Use these methods to put this into practice:

- Check the radiological survey data.
- Become familiar with the radiological conditions in the work area especially locations with the highest dose rate.
- Stay as far away from the source of radiation as possible.
- If you experience a pause or delay while working, move to areas with lower dose rates or move entirely outside the radiological area.
- Use remote handling or extended reach devices to increase the distance.
- Move the source away from your work area when completing other tasks.

To summarize, keep the following principle in mind:
When working near or with a small source of radioactive source, such as a hot spot, doubling the distance between you and the hot spot reduces the dose rate to ¼ of its original value. This follows the principle of the inverse square law (Dose Rate/Distance^2).

The third measure to reduce your radiation dose involves using shielding as an engineering control. Make use of these shielding practices:

- Shield your eyes with safety glasses or goggles.
- Use the appropriate shielding material as different materials shield you from different types of radiation.
- Design facilities to incorporate permanent shielding.
- Store radioactive sources in shielded containers when possible.
- Use temporary shielding to help reduce the total dose including the expected dose for installation and removal.

Other Engineering Controls for ALARA

Along with using shielding as an engineering control, source reduction can also be an effective means to reduce radiation dose to the workers. This includes:

- Flushing radioactive systems to remove the radioactive material.
- Decontamination of equipment and / or working areas.
- Removal of contaminated items and radiation sources prior to personnel working in the area.

Reducing Internal Radiation Dose

In addition to external radiation dose, radiological workers have a potential for internal radiation dose from radioactive contamination. Even small amounts of radioactive materials entering the body can pose a significant radiation dose.

Radioactive material can enter the body through any of the following pathways:

- Cuts/Wounds: Radioactive material can directly enter the bloodstream through cuts, wounds, and rashes.
- Absorption: Radioactive liquids can be absorbed directly through the skin.
- Ingestion: Radioactive materials can enter the body through the mouth.
- Inhalation: Airborne radioactivity can be inhaled through the nose or mouth.

There are two protective measures used to reduce internal radiation dose:

Control and containment of radioactive material

- "Fixing" contamination in place with paint or other coatings
- Using gloveboxes or fume hoods to control loose contamination
- Routinely decontaminating work spaces
- Keeping work areas under negative air pressure when handling radioactive liquids, powders, or contaminated items

Personal protective equipment (PPE)

- Gloves
- Lab coats

- Coveralls
- Shoe covers
- Caps or hoods
- Respirators

Minimizing Radioactive Waste

One of the potential consequences of working with radioactive materials is the generation of radioactive waste. This radioactive waste must be properly disposed.

Examples of radioactive waste materials include:

- Paper
- Gloves
- Glassware
- Rags
- Brooms and mops

The ALARA concept also applies to minimizing radioactive waste. This will reduce personnel dose associated with the handling, packaging, storing, and disposing of radioactive waste. It also reduces costs for Argonne and can ultimately save valuable space in national waste disposal sites. It is each worker's responsibility to minimize the amount of radioactive waste generated.

Methods to Minimize Radioactive Waste

Here are some methods that can be used to minimize radioactive waste:

Radioactive Waste Pre-job Planning:

- Only bring tools, equipment, and supplies you need in a radiological area (especially contaminated areas). This includes bulk supplies, like an entire container of bags or wipes. Only bring in what you need.
- Unpack equipment and tooling in a clean area to avoid packaging material being added to radiological waste.
- Use tools and equipment identified for contaminated areas (as they may be already slightly contaminated from previous work).

Prepare or stage the work area to make cleanup of spills easy.

- Cover tools and equipment, to prevent them from becoming contaminated
- Sleeve hoses and tubing that you wish to keep clean

Dispose of the waste materials in the proper containers and have waste removed from the work area on a timely basis.

MODULE 5 – PERSONNEL MONITORING

Module Objectives

We have discussed how the human body can be exposed to radiation both externally and internally. Checking the radiation dose an individual receives involves assessing radiation dose due to both external and internal radiation sources. In this module, we will look at the personal dosimeter, which measures external dose, and a variety of methods used to measure internal dose. We will also discuss how a worker's dose records are maintained at Argonne.

Upon completion of this module, you will be able to:

- State the purpose and worker responsibilities for each of the external dosimeter devices used at the site.
- State the purpose and worker responsibilities for each type of internal monitoring method used at the site.
- State the methods for obtaining radiation dose records.
- Identify worker responsibilities for reporting radiation dose received from other sites and from medical applications.

External Dosimeter Devices

A dosimeter is a device used to measure the total accumulated radiation dose. Dosimeters provide a permanent record of each worker's individual radiation dose. They come in a variety of types, and Radiological Safety determines which one should be used. These devices do not provide any protection against radiation; they just measure the amount of radiation that you are exposed to.

Proper Orientation of the Dosimeter

An Argonne-issued dosimeter is not meant to determine the total radiation dose you received offsite or from some other location. Therefore, you should be very diligent to wear the dosimeter when working in an area where there is the potential for exposure at Argonne, and not wear it offsite unless you are performing a work activity for Argonne. Your personal dosimeter measures your whole-body dose.

Primary dosimeters should be worn on the chest area. This area is on or between the neck and the waist, because the major blood-forming organs and other vital organs of the body are in this section, and that is where we want to determine the whole-body dose.

The dosimeters are labeled with your name, employee badge number, building and dosimeter rack number, dosimeter type, and the monitoring period (date due to be returned). In addition, the dosimeter has several filters. You will see an opening with a thin plastic window on the dosimeter and on the inside, there are plastic and metal filters that allow us to differentiate between types of radiation the dosimeter is exposed to.

Keep in mind, the dosimeter is only useful if it is properly worn. Wear the dosimeter with your name and information section-facing forward (the opening and the filters will also face forward). In addition, it should be attached such that it will not continually flip around or swing away from your body while you are working. Remember, your dosimeter measures your radiation exposure only if it is with you when you when you are working!

When you are not wearing your dosimeter, keep it in your assigned rack at the spot with your name. If you are assigned a finger ring dosimeter, keep it over the clip of your dosimeter when not in use on your finger.

Types of Dosimeters

There are times when other dosimeters may be used in addition to your primary dosimeter. These supplemental dosimeters include extremity dosimeters (e.g., finger rings), electronic dosimeters, and multiple other dosimeter sets.

The need for supplemental dosimeters will be specified on radiological postings, in radiological work permits and/or in other work control documents or procedures.

You are responsible to obtain and wear supplemental dosimeters when they are required.

Extremity Dosimeters

A worker who stands behind a shield while handling radioactive materials may receive a much higher dose to the extremities than to the whole body. This worker requires the use of an extremity dosimeter. Ring dosimeters, or finger rings, are the most used extremity monitors. They measure the radiation dose to the hands.

The rings contain a single chip. The label of the finger ring should be closest to the radiation source. So, if you are holding a radiation source, then the label should point inward. If you are placing your hands in a radiation field without handling the radiation source, the label should point outward.

If you suspect that your dosimeter has been damaged, report the damage and return it to Health Physics.

Electronic Dosimeters

The digital or electronic dosimeter (ED), sometimes called an ‘alarming dosimeter,’ displays your radiation dose in real time. They can also be set to alarm when a predetermined dose limit or dose rate has been reached.

Electronic dosimeters should be worn close to or with your primary dosimeter. RWPs, postings, work planning and control procedures or Health Physics may specify the exact location for wearing primary and supplemental dosimeters. It is your responsibility to follow these instructions. You may also be responsible to log in and out your ED readings when entering and exiting the radiological work area.

If the integrated dose alarm on an electronic dosimeter sounds:

- Place work activities in a safe condition
- Warn others
- Immediately exit the area
- Notify Health Physics

If rate alarms are being used to determine when a worker may be in a radiation field higher than the set points of the RWP, the alarm indicates:

- The material may need additional shielding.
- The worker may need to increase the distance between themselves and the radioactive material.

Radiological Work Permit/Dosimetry

For all radiological work there will be an associated RWP. You as the worker must be briefed on the correct RWP and have signed the concurrence page. For all work activities, you have the responsibility to know the RWP associated with your work. It is not uncommon to have multiple RWPs in one area. It is extremely important to know the differences between different RWPs that you may use. This is particularly important when it comes to hold points, control limits, and dosimetry selection.

During radiological worker practical training you will be required to state hold points and control limits as well as select the correct type of dosimetry. The RWP will specify the minimum required dosimetry. Electronic dosimeter (sometimes called alarming dosimeter) may also be required.

External Monitoring and Your Responsibilities

The responsibilities of workers who wear external dosimeters include:

- Using a dosimeter whenever required
- Wearing the dosimeter with the label facing out between the neck and waist
- Not wearing the dosimeter at any offsite location (unless required)
- Storing dosimeters in an area that is equivalent to natural background
- Returning the dosimeter for processing, as directed, on a timely basis
- Reporting any dosimeter that is lost, found, or suspected to be damaged to Health Physics

Properly Worn External Dosimetry

The photos below illustrate both improperly and properly worn external dosimetry.

Incorrect! Dosimeters are sensitive to moisture and solvent.

Incorrect! The dosimeter was left on a lab coat, which is near a radiological work area. It may record high background radiation exposure while not being worn.

Incorrect! This dosimeter is too low. Do not hang it off a key chain or clip. Remember, it should be centered between the neck and waist and facing away from you.

Incorrect! The dosimeter is facing backwards. The measured skin dose from low penetration radiation will be inaccurate.

Correct! The dosimeter is centered between the neck and waist and faces away from you.

Internal Dosimetry Program

While the dosimeter is designed to measure radiation dose from sources outside the body, workers who have potential for intake of radioactive material are monitored as part of the internal dosimetry program. There are several methods used to detect and measure radioactive material inside the human body. These methods include bioassay sampling and use of a whole-body counter.

Bioassay (biological assay) methods analyze a worker's urine or fecal samples for the presence of radioactive material. In other words, we calculate the amount of radioactive material taken into your body (by inhalation, ingestion, absorption, or injection) by analyzing the radioactive material in your excrement coming out of your body.

Collection kits with directions are provided to workers prior to employment (for a baseline sample), and on a routine schedule as prescribed by your supervisor and Health Physics. If a positive result is found, additional samples will be required to determine the internal radiation dose. Once the amount of radioisotope is known, a dose estimate can be calculated for the whole body and/or any individual organs that the specific radioisotope may affect. The frequency for the routine and special sampling depends on the half-life of the radioactive material, the bodily excretion rate and the schedule for working with radioactive materials.

Whole-body counters are very sensitive detectors that directly measure X-rays and gamma rays released by radioactive material inside the body. They are sensitive enough to identify the specific radioisotopes in the body that emit that radiation. To detect radioisotopes that emit alpha radiation, we need to perform a bioassay analysis.

Internal Monitoring and Your Responsibilities

Workers, who are identified as part of the internal dosimetry program, have the following responsibilities to ensure they are properly monitored:

- Report to the body counting facility when routine counting is scheduled, or when Health Physics or your TMS training profile indicates that you should do so.
- Keep Health Physics informed by providing information on previous exposure and current work with radioactive materials, especially materials with a short half-life.

- Notify Health Physics if you had a medical procedure or test done that involved radioactive material.
- Submit urine or fecal samples when routine sampling is scheduled, or when Health Physics or your TMS training profile indicates that you should do so.

Exposure from Other Facilities

Argonne workers may perform radiological work at other facilities. This includes work at universities, corporations, other DOE facilities, environmental cleanup projects, etc. These other facilities normally require a current dose report from personnel prior to their work at their facilities. The dose report may be obtained from the Dosimetry Group. If you are required to wear a dosimeter at another site, that facility's dosimetry service provider will generally issue it.

Do not wear an Argonne dosimeter (any type) offsite, unless specifically authorized to do so.

It is your responsibility to keep Argonne Health Physics informed of any occupational radiation exposure you may receive at another facility. Your administrative control levels and dose records must be monitored and documented.

Dose Record Access

The Dosimetry Group, located in Building 202, keeps permanent records for internal and external radiation dose.
Written dose reports are provided annually to each worker, and you may request one at any time throughout the year as it may be needed for trips to non-Argonne facilities. When you are issued a temporary dosimeter, Health Physics will fill out form ANL-141. This will ensure that you receive your report in the mail. You may also contact your local HP office to receive any dose information.

MODULE 6 – ACCESS CONTROLS AND POSTINGS

Module Objectives

You have become familiar with ALARA and methods for monitoring external and internal dose. In this module, we will discuss other work controls established to help keep your dose ALARA. Examples of these controls are the Work Planning and Control (WPC) Work Control Document (WCD) or procedure, Radiological Work Permits (RWPs), radiological postings, and personnel contamination monitors.

Upon completion of this module, you will be able to:

- State the purpose of and information found on Work Planning and Control documents.
- Identify the colors and symbol used on radiological postings.
- State the radiological and disciplinary consequences of disregarding radiological postings, signs, and labels.
- Define the areas controlled for radiological purposes.
- Identify the minimum or recommended requirements for entering, working in, and exiting various radiological areas:
    - Radiological Buffer Areas
    - Radiation Areas
    - Radioactive Material Areas
    - Underground Radioactive Material Areas
    - Soil Contamination Areas
    - Fixed Contamination Areas
    - Contamination Areas
- Identify the areas a Radiological Worker Level I trained person may enter.
- Identify the purpose and use of personnel contamination monitors.
- State two items established by LMS-PROC-45, "Managing Radioactive Material Inventories"

Work Planning and Control

Work planning and control (WPC) is the process used to identify hazards and controls and to provide for the health and safety of all Argonne employees and contractors, its visitors, the public, and the environment. WPC focuses on four key areas in work planning and control: hazard analysis, control selection, work approval, and work authorization.

The Radiological Work Permit (RWP), which will be discussed later, is part of the WPC process that focuses on protection and controls from radiological hazards.

There are two general categories of work, each of which requires specific Work Control Documents (WCDs) and, if applicable, procedures to perform the work activities.

Experimental Work is work in which the motivation is to test a thesis and, therefore, the exact outcome is unknown.

Non-experimental work is routine and non-routine work for which the outcome is generally known or can be predicted. The three types of non-experimental work are:

- Skill of the Worker for routine work activities: Those skills that are intrinsic to a profession, craft, or discipline that have been gained through a combination of training, education, and experience, and that allow those skilled individuals included in those groups to perform routine or low hazard assignments in a manner that requires minimal to no prior planning, and meets accepted standards for safety.
- Procedure-controlled work: For situations where written procedures have been established.
- All other non-experimental work activities: Includes non-routine work or one-time projects and activities.

Work that is excluded from the WPC process includes routine work, tours, inspections, and other low hazard work and activities by personnel where formal job planning and controls beyond simple precautions are not warranted.

The Radiological Work Permit as a Part of WPC

The WPC process requires a significant amount of thought about how the job will be done and what protection will be required to safely perform the task. The Radiological Work Permit (RWP) is part of the WPC process, and the final permit for entrance into a radiological area. WPC documents describe all hazards associated with the planned work, whereas RWPs describe only the radiological conditions.

Note that work that is not performed in a radiological area does not normally require an RWP, unless the potential to create a radiological area exists.

The RWP describes the activity to be accomplished in a radiological area, and documents the radiological hazards and their associated controls. The "Concurrence" page documents that workers have reviewed the RWP, are informed of the radiological conditions and controls that must be implemented during authorized work activities, and will comply with the RWP. Each worker is responsible to read and sign the RWP prior to entry. The RWP also provides a method of dose tracking for specific work activities.

Module 10 will go into more depth about what information is contained in an RWP, implementation of RWPs, and worker responsibilities at Argonne.

Initiating WPC Documents and RWPs

Argonne job supervisors or person in charge (PIC) should initiate a WPC Work Control Document (WCD) and forward it to Health Physics if the job is to be performed in a radiological area (that is, one of the following areas) or involves any other significant radiological hazard:

- Radiation Area, High Radiation Area, Very High Radiation Area
- Contamination Area, High Contamination Area

- Airborne Radioactivity Area

If you are unsure whether the work activity may require an RWP, always consult with Health Physics. Once Health Physics receives the WCD, they will discuss the job specifics and radiological controls with the job supervisor and write an RWP for the job.

Worker's Rights

The worker's rights with respect to radiological safety, and safety in general, include:

Reporting Safety Issues

You have the right to notify your employer of workplace hazards without reprisal. You may ask that your name not be used when reporting workplace hazards (that is, any call can be made anonymously). Below is a preferred order of contact in reporting safety concerns:

- Your supervisor
- Division management
- The Argonne Safety Concerns email at safety@anl.gov
- Human Resources (2-2960), Legal (2-3040)
- The DOE Chicago Operations Office, Employee Concerns Program at Argonne (800-701-9966)

To report fraud, waste, abuse, misconduct and/or harassment contact:

- Your supervisor
- Division management
- Human Resources (2-2960), Legal (2-3040), or the Ethics and Compliance Officer (x6376) or (ethicsofficer@anl.gov)
- The Argonne Ethics and Compliance Line (877-587-2449)
- The DOE Chicago Operations Office, Employee Concerns Program at Argonne (800-701-9966)
- The DOE Office of Inspector General (800-541-1625)

Nature of Hazards

The communication of hazards and their associated controls is primarily done through the Work Planning and Control (WPC) documentation and the Radiological Work Permit (RWP) that you review and sign prior to performing the work outlined in those documents. In addition, the posting and labeling of hazards at the work location is another means of communication for personnel working in the area.

Dose Monitoring Records

You have the right to view your dose monitoring records at any time. Written dose reports are mailed annually to each worker to the address on file, and you may request one at any time throughout the year. In addition, your area HP office may have an electronic version of your dose records that you can discuss with them. You also have the right to observe monitoring and measuring of hazards and be notified when monitoring results indicate an overexposure.

You also have the right to:

- Access copies of standards, controls and procedures that apply to your workplace.
- Request and receive results of inspections and accident investigations.
- Access your accident and illness records and copies of your medical records.

Stop Work Authority

All Argonne employees, visitors, facility users, and contractors are empowered and obligated to stop any activity that they deem to pose an immediate danger to themselves, any other site occupant, the public, or the environment. This authority is referred to as Stop Work Authority.

You have the right to decline to work and/or stop work if you believe that there is insufficient time to seek an effective solution through the normal hazard reporting and abatement procedures.

For more information on Stop Work Authority, see LMS-POL-1.

Training

All workers have the right to receive the training necessary to complete the jobs assigned to them. This training is identified through the Training Management System (TMS), which triggers the required training based on your responses on the Job and Hazard Questionnaire (JHQ).

The JHQ is designed to identify environment, safety and health training requirements and suggestions related to the individual's job; it also provides information that assists with functions such as medical evaluations and surveillance, exposure monitoring, hazard assessment, certifications, and more.

It is the combined responsibility between you and your supervisor to ensure your JHQ is complete, accurate, and updated with significant changes in job duties so that the right training can be identified.

Radiological Postings

Along with the RWPs, another important control for radiation protection are the radiological postings used to communicate radiological hazards in the workplace. This posting system uses signs with specific radiological designations and labeling to clearly communicate radiological hazards present and safety requirements. The standard colors to communicate radiological hazards are yellow and magenta.

Postings or labels also indicate the presence of radioactive material by having the ionizing radiation trefoil present. The postings are placed in plain view on wall and/or doors at the entrance to the areas. Do not enter radiological controlled areas unless you have met the entry requirements. If you are not sure if you have met the requirements to enter a radiological controlled area, contact your supervisor or Health Physics.

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. The radiological postings are designed to identify a radiological controlled area and alert you of the presence of radiological hazards. Each of these items represents a potential consequence of disregarding the postings:

- Personal liability
- Unnecessary exposures
- Excessive personal exposure to radiation
- Personal contamination
- Disciplinary action
- Loss of job
- Shutdown of work site or facility

Controlled Areas

A Controlled Area is any area where access is controlled in order to protect personnel from exposure to radiation and/or radioactive material. A controlled area may be defined by a barrier, such as a security fence, and may contain other buildings or labs within the area.

You will see other radiological postings, such as Radioactive Material or Radiation Area, within a controlled area.

This sample posting indicates that the controlled area has no specific radiological designation. This means that the potential radiological hazard is relatively low. Personnel entering only Controlled Areas without any other radiological designation are not expected to receive a dose of more than 100 mrem in a year.

Persons who have completed General Employee Radiation Training (GERT) may make unescorted access to Controlled Areas without any other radiological designation. An escort is required if additional radiological designation is posted.

Controlled Area entry requirements:

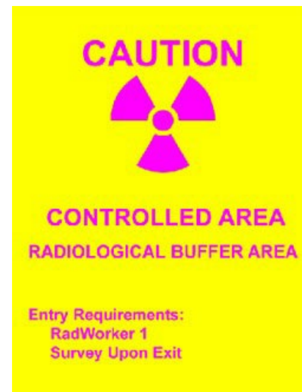
- Completion of GERT training.
- Can access unescorted once GERT has been completed.
- A visitor or individual with a demonstrated need to enter the area requires an escort.
- Visitors and individuals who have not completed GERT training may be escorted into controlled areas without a dosimeter.

Radiological Buffer Area

A Radiological Buffer Area (RBA) is an intermediate area established to prevent the spread of radioactive contamination or prevent overexposures to radiation sources. It may contain a Radiation Area (RA), High Radiation Area (HRA), Very High Radiation Area (VHRA), Contamination Area (CA), a High Contamination Area (HCA), or Airborne Radioactivity Area (ARA). Contamination monitors are required at the exit from RBAs that contain CAs, HCAs, and ARAs. RBAs are used at Argonne and are found at other DOE facilities.

Radiological Buffer Area entry requirements:

- Level I Radiological Worker Training is required when personnel are in the RBA but NOT working in a radiological area that requires Level II Radiological Worker Training.
- Visitors are not required to take GERT and are not issued dosimeters for escorted entry into controlled areas.
- Escorted individuals (those coming on site in order to do work that they are compensated on) are required to take GERT and may be issued a dosimeter for entry into controlled areas.
- Visitors and escorted individuals must be escorted by an individual that has the appropriate training for the area.

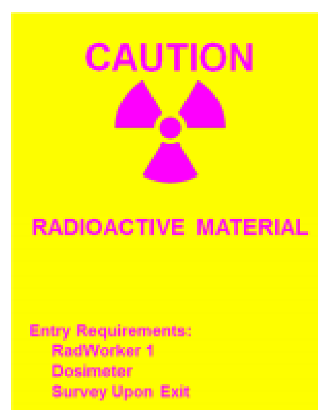


Radioactive Material Area

A Radioactive Material Area (RMA) is an area where sealed sources and/or properly contained/non-dispersible radioactive material may be used or stored. This includes equipment, components, or materials that have been exposed to contamination or have been activated, as well as dispersible radioactive material in a tightly sealed container.

Keep in mind that Controlled Areas, RBAs or RMAs are not Radiological Areas. Radiological Areas are those areas where significant radiological hazards may be present, such as radiation fields and/or radioactive contamination. As a reminder, Radiological Areas consist of the following:

- Radiation Areas, High Radiation Areas, and Very High Radiation Areas
- Contamination Areas and High Contamination Areas
- Airborne Radioactivity Areas



Radioactive Material Area entry requirements:

- Level I Radiological Worker Training is required
- A dosimeter may be required (It is your responsibility to observe the radiological posting's entry requirements).
- Visitors are not required to take GERT and are not issued dosimeters for escorted entry into controlled areas.

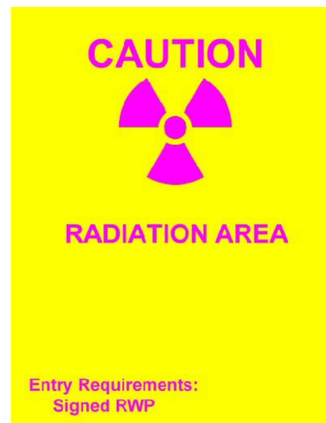
- Escorted individuals (those coming on site in order to do work that they are compensated on) are required to take GERT and may be issued a dosimeter for entry into controlled areas.
- Visitors and escorted individuals must be escorted by an individual that has the appropriate training for the area.

Radiation Area

A Radiation Area is an area, accessible to individuals, in which radiation levels could result in an individual receiving an equivalent dose to the whole body in excess of 5 mrem in one hour, but less than or equal to 100 mrem/hr. This is based on dose rates measured 30 cm (1 foot) from the source of radiation. The source could be radioactive material or a radiation generating device, for example, an X-ray machine. When working in Radiation Areas, workers should be mindful of the higher dose rate areas and move to low dose areas when able.

A Radiation Area is one of the radiological areas, and thus requires an RWP for entry. The RWP will contain any additional requirements, like periodic surveys to be performed by Health Physics technicians during work, among others. Radiation Area entry requirements:

- Level I Radiological Worker Training is required
- Dosimeter
- Sign in on the RWP (and WCD, if applicable)
- Notify Health Physics (if requested)
- Know the dose rates from radiological surveys
- Individuals being escorted into Radiation Areas must complete GERT training and must wear a dosimeter (no visitors)



Contamination Area and High Contamination Area

Contamination Area is any area, accessible to individuals, where removable surface contamination levels exceed or are likely to exceed the removable surface contamination values specified in appendix D of 10 CFR 835, but do not exceed 100 times those values.

A High Contamination Area is an area accessible to individuals where removable surface contamination levels exceed or are likely to exceed 100 times the removable surface contamination values specified in appendix D of 10 CFR 835.

An Airborne Activity Area is an area accessible to individuals where significant radioactivity hazard is present.

To enter Contamination, High Contamination, and Airborne Radioactivity Areas, you are required to have:

- Appropriate Radiological Worker Training (Level II)
- Successful completion of Practical Factors Evaluation
- PPE, as specified in the RWP, which may include:

Lab coats, gloves, shoe coverings, full Tyvek coveralls, sleeves, and aprons
Respirators
Personal dosimetry (as dose rates can be a factor in contamination areas)

- Signature on the RWP

High Radiation Areas and Very High Radiation Areas

High Radiation Area is any area accessible to individuals in which radiation levels could result in an individual receiving a deep dose equivalent in **excess of 100 millirem in 1 hour at 30 centimeters from the radiation source or from any surface that the radiation penetrates**.

Very High Radiation Area is any area accessible to individuals in which radiation levels could result in an individual receiving an absorbed dose in **excess of 500 rads in one hour at 1 meter from a radiation source or from any surface that the radiation penetrates.** Very High Radiation Areas are not typically accessed by individuals.

Only individuals that have Level I Radiological Worker Training with the High Radiological Practical or Level II Radiological Worker Training can access these areas.

Radiological Workers who have lower level training should be cognizant of this and not access these areas EVEN IF they are with an individual with the appropriate training.

More information and discussion of hazards in these two types of areas will be discussed in a later section for individuals taking Radiological Worker Training Level II.

Other Postings

Some controlled areas may display postings with multiple area designations. This means more than one type of hazard is present. The most common practice is to list the most significant hazard first on the posting.

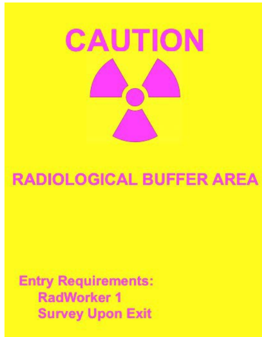
Radiological Worker Level Entry Requirements

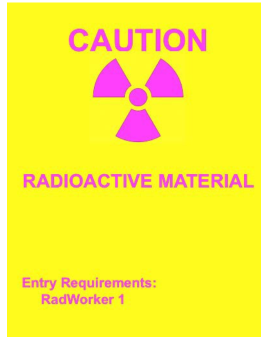
Persons qualified at the Radiological Worker I level can make unescorted access to areas posted with the following designations: Controlled Area, RBA, RMA, and Radiation Area.

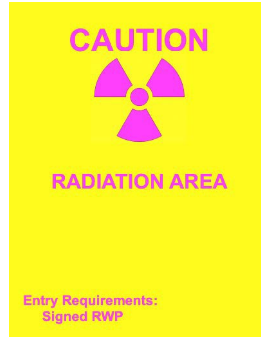
There are other radiological area designations you may encounter that require Radiological Worker II qualifications. These are Contamination Areas, High Contamination Areas, High Radiation Area, Very High Radiation Area or Airborne Radioactivity Areas. Visitors and escorted individuals are NOT allowed to access these areas even if they are with an escort that meets the training requirements.

Radiological Worker I

- Unescorted access to the following areas:

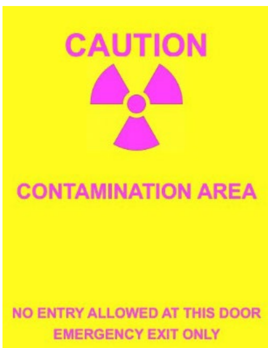


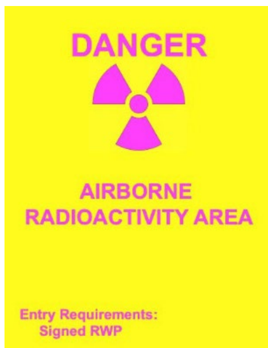


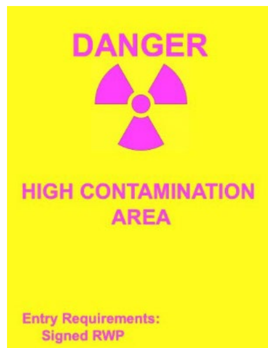


Radiological Worker II

- These areas have uncontained/dispersible radioactive material

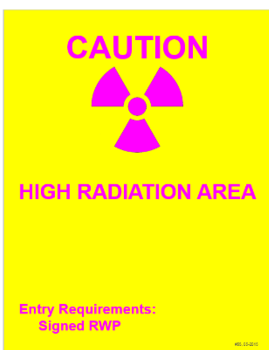






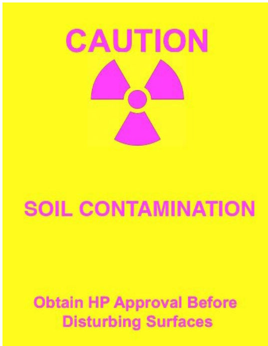
Radiological Worker II or High Radiological Worker

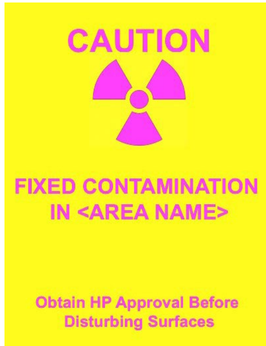
- These areas have radioactive sources that can create extremely high dose rates

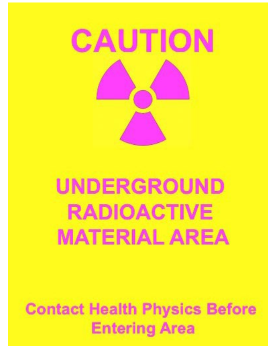


Additional Postings

You may encounter these additional postings, which may not be within a Controlled Area. Contact Health Physics should you have any questions, or when engaging these areas.







Soil Contamination Area

This is an area where soil below the surface contains radioactive contamination.

Fixed Contamination Area

This is an area or equipment that contains radioactive material that is not easily removed by physical contact (i.e. wiping, brushing or cleaning without harsh chemicals). The fixed contamination can be sealed with two coats of paint of noticeably different colors, so that the need to repaint the outer coat would be obvious when the alternate-color paint underneath can be seen (due to wear or chipping). Finally, the words “CAUTION – CONTAMINATION UNDER PAINT” (or similar) are stenciled over the top layer of paint.

Underground Radioactive Material Area

In this area, the soil below the surface contains radioactive materials such as pipelines, tanks, or demolished buildings, etc.

Personnel Contamination Monitors

You saw that the use of a personnel contamination monitor is an exit requirement for a Radiological Buffer Area that contains a CA, HCA and/or ARA. There are several types of personnel contamination monitors available for use. All are designed to detect low levels of radiation released by radioactive contamination that may be present on a worker’s clothing or body. Personnel contamination monitors are checked weekly by Health Physics technicians to ensure that they are operating appropriately.

Personnel contamination monitors are located at the exit points of areas where the potential for removable contamination exists. While you must use these devices when exiting, it is a good idea to use the contamination monitor when entering too; especially on rainy days when the presence of naturally-occurring radon on your hands and shoes may be high enough to alarm the monitor. This gives you more information to give to the Health Physics technician if the personnel contamination monitor alarms when you are exiting the lab.

For manual units, check to see if the rate meter (generally at the top of unit) is giving a response before entering an RBA. These units have analog rate meters. When using a manual monitor, you must confirm that the unit is operating properly, use the appropriate counting time, and decide whether the observed count rate is different from background. The monitors will alarm when a preset limit is reached). Do not adjust any settings on these machines.

Automatic monitors, by design, will determine the required counting time. The monitors will stop operating if conditions are not satisfactory to monitor you. These conditions include: a high background, the unit runs out of gas, or an electronic fault. Before entering an RBA, read the monitor display to ensure it is operating properly. It should read “Ready for Use” or a normal display to show that the unit is operable. View the display on your way in and before use.

Exiting the Radiological Buffer Area

Before you enter the radiological buffer area, you should confirm that the hand and foot monitor is functioning properly.

When you are ready to exit the RBA fully, proceed to your lab’s hand and foot monitor. If you were just working in a contamination area you may be required to have a whole-body survey or survey portions of your personal protective equipment. (This will be covered in detail in a later module if it is required of you.)

For manual hand and foot monitors, you will survey hands and shoes for 5 to 7 seconds. If no increase in response is heard, you may step over the established boundary. You may also follow the operator aid located on or near the device.

For automatic hand and foot monitors simply step on to the hand and foot monitor, place hands and feet in proper orientation (monitor will not start counting until this is correct). Wait for the monitor to indicate that it has finished counting and no contamination was detected. Then step over the established boundary.

Use of an automatic hand and foot monitor is demonstrated in the video at the end of this training.

Reporting Radioactivity Hazards for Radiological Facilities

LMS-PROC-45 establishes the process for managing all radioactive materials at Argonne. It applies to all accelerators and radiological facilities (less than Hazard Category 3), and buildings that contain radioactive inventory items in use or storage except for waste facilities operated by Nuclear Waste Management (NWM). It establishes the processes for tracking, acquiring, updating, transferring and wasting radioactive material items. Additional requirements apply to items that qualify as nuclear materials (special and other) and sealed radioactive sources (see NUCMAT and LMS-PROC-171 for details).

Each facility is required to track all current radioactive material items in CURIE, according to its administrative control limits (ACL), and to perform a physical inventory of each item annually. Exceeding the ACL could result in changing the hazard categorization and violating the conditions of the hazard analyses applicable to the facility, which carries both safety implications and potential Price-Anderson Amendment Act (PAAA) fines.

Note that the movement of radioactive materials between facilities must be done by the Material Control & Accountability (MC&A) group according to LMS-PROC-202. At no time should the material be transferred in non-DOE vehicles.

For more information on:

- Nuclear materials, see the Nuclear Material User's Manual (NUCMAT)
- Accountability and control of sealed sources, see LMS-PROC-171
- Acquisition and receipt of radioactive materials, see LMS-PROC-174
- Onsite transfers of radioactive material, see LMS-PROC-202

MODULE 7—RADIOLOGICAL EMERGENCIES

Module Objectives

When off-normal radiological conditions and emergency situations arise, monitoring systems provide you with warnings. It is crucial that you become familiar with these alarms and know the response to each. Responding appropriately helps minimize exposure and personal contamination during these situations.

Upon completion of this module, you will be able to:

- State the purpose and types of emergency alarms.
- Identify the correct responses to emergencies and alarms.
- State the possible consequences of disregarding radiological alarms.
- State the site administrative emergency radiation dose guidelines.

Types of Monitors

Monitoring systems are used to warn personnel when off-normal radiological conditions exist. Equipment that monitors radiation dose rates and airborne radioactivity levels is placed throughout the lab. Below are various types of monitors and their associated alarms.

BACKSCATTER ALARMS (Area radiation monitor)

Purpose: To detect low level energy X-rays.
Location of alarm: Mounted near analytical X-ray machines to detect excessive leakage of X-rays (APS only)
Alert trigger: Alerts due to excessive leakage of X-rays

ELECTRONIC (ALARMING) DOSIMETER

Purpose: To track an individual dose during specific job operations; issued by Health Physics
Location of alarm: Worn in addition to the dosimeter on the chest between neck and waistline
Alert trigger: Alerts when a preset dose limit is reached or the dose rate exceeds a preset level

CONTINUOUS AIR MONITORS (CAM)

Purpose: To measure and record the level of airborne radioactive contamination
Location of alarm: In work area
Alert trigger: Alerts if an abnormal concentration of airborne radioactivity is present

HAND AND FOOT MONITORS (Personal Contamination Monitors)

Purpose: To detect low levels of radioactive contamination
Location of alarm: Located at exits of Radiological Buffer Areas
Alert trigger: Alerts when contamination is found on body/clothing when exiting a controlled area

AREA RADIATION MONITORS

Purpose: To warn of abnormal radiation dose rates
Location of alarm: Generally used at accelerator facilities such as APS, ATLAS; also used at facilities that use highly radioactive sources (hot cells and irradiators)

Alert trigger: Alerts if elevated radiation dose rates are present

Correct Responses to Alarms

When an alarm is triggered on a monitoring system, it is crucial that you know how to respond. While your response will vary based upon the type of alarm, think of your response in terms of four separate actions. These actions are: STOP. WARN. EXIT. NOTIFY. See the table below for more details.

Alarm	Area Radiation Monitors	Electronic Dosimeter	Continuous Air Monitors (CAM)	Hand and Shoe Monitor
Stop	Shut down work	Shut down work	Shut down work	Shut down work
Warn	Alert others	Alert others	Alert others	Alert others
Exit	Leave area	Leave area	Leave area	Stay in the area to avoid spreading comtamination
Notify	Person in charge Facility Manager Health Physics	Person in charge Health Physics	Person in charge Facility Manager Health Physics	Health Physics

Disregarding any type of radiological alarm can lead to:

- Excessive radiation exposure
- Spread of contamination
- Disciplinary action

Correct Responses to Emergencies

Working in a radiological environment requires more precautionary measures than performing the same job in a non-radiological setting. If an emergency arises during radiological work, your response actions may be necessary to ensure personnel safety.

A detailed response for radioactive spills will be discussed later for individuals taking Radiological Worker Training Level II. For those taking Radiological Worker Training Level I or High Radiological Worker Training, it is important to be aware of what activities are occurring in a laboratory beside your own. You could easily be working in an RBA where activities are occurring in a Contamination Area (CA). A radioactive spill could occur in your area even if you personally are not working with dispersible radioactive material.

For radioactive spills, immediately exit the area where the spill is located without attempting to stop or secure the spill unless you are trained and qualified to do so. Promptly call 911 to report the spill to the Argonne Fire Alarm Office. If you are using a cell phone, dial 630-252-1911. Note: calling 911 from your cell phone, rather than 630-252-1911, may delay response as you will first be routed to the DuPage County dispatch center, which may then either route the call to the Argonne Fire Alarm Office or relay the information to them.

If a fire alarm or tornado warning sounds while you are in a radiological area or an RBA, you must evacuate. While exiting the area and only if it is safe to do so, doff PPE as you are able. Do not survey on the hand and foot monitors. **Only doff PPE in this situation if you are able to walk and doff simultaneously**. Once you exit the area, keep remaining PPE on. While exiting the building, avoid contact with others and separate yourself from others at the designated meeting location. Even after the alarm has been cleared, wait for instructions from Health Physics.

If an injury occurs in a radiological area, the recommended response depends on the nature of the injury. For cuts or wounds, the victim should be moved away from high level sources of radiation and potential sources of radioactive contamination. Remember, injury takes precedence over radiological concerns. If there is a chance that moving the victim could result in greater injury (for example a spinal injury), DO NOT attempt to move the victim from the radiological area. In either case, call 911 (or (630) 252-1911 from a cell phone) for emergency response. Also, ask the operator to contact Health Physics.

In addition, if you call 911, then:

- Stay on the phone until all questions from the 911 operator are answered. If you agree to disconnect the call, then ensure that they have your name and call back number should additional questions arise.
- Be prepared to give the nature of the emergency and associated details including your location and the detailed location of the emergency (building, room number, and specific details to identify the emergency).
- Be prepared to relate all major hazards that the emergency responders and others in the area may be exposed to.

To report non-emergency incidents and near misses:

- Still call 911 or 630-252-1911. The operator will take your information and route the report to the appropriate parties.

Considerations and Guidelines in Emergency Operations

In extremely rare cases, emergency exposure to high levels of radiation may be necessary to rescue personnel or protect property. In these cases, an official in charge guides the operation using careful judgment due to the substantial risk to personnel. The official’s judgment is guided by many variables that include determining the risk versus the benefit of an action and deciding how best to implement the action.

Radiation workers who volunteer to perform lifesaving or rescue operations must be thoroughly informed of the hazards, and must be trained and qualified to work under such conditions.

The DOE maintains emergency dose limit guidelines for these types of situations. See the table below for details.

DOE GUIDELINES FOR CONTROL OF EMERGENCY EXPOSURE		
Dose Limit (Whole Body)	Activity Performed	Conditions
5 rem	All activities	
10 rem	Protecting major property	
25 rem	Lifesaving or protection of large populations	Where lower dose limit is not practicable
>25 rem	Lifesaving or protection of large populations	Only on a voluntary basis to personnel fully aware of the risks involved

Radioactive Material Uptake Response

Chelation Therapy vs. Blocking Agents

If a large uptake of radioactive material occurs, chelation therapy might be used in order to help the body discharge or excrete the radioactive material (RAM).

Chelation Therapy – is the administration of chelating agents (usually organic compounds) that are either swallowed or injected. The body can readily discharge the chelating agents; however, while the agents are in the body, they grab radioactive material on their way out to help the body discharge the radioactive material. Chelation therapy is only administered by Health and Employee Wellness personnel.

Blocking Agents – are different from chelation therapy (which is taken after a known uptake to facilitate discharge) in that blocking agents are taken before exposure to prevent uptake. Sometimes there are nuclear radiological events in which potassium iodide (KI) tablets are distributed because of a release of radioactive iodine. This will essentially flood the body with non-radioactive iodine so that your body will not absorb any radioactive iodine. If radioactive iodine enters the body, it will be discharged by the body. Note: If you take KI tablets after the exposure, little benefit will result.

MODULE 8 – HIGH RADIATION AREAS

Module Objectives

Earlier in this course, you became familiar with the risks associated with low to moderate levels of radiation. In this module, you will become familiar with “high” and “very high” radiation as well as locations and sources that produce these levels of radiation at Argonne, and the minimum requirements and controls established for working in these areas.

Upon completion of this module, you will be able to:

- Identify sources and locations on site that produce these levels of radiation.
- Know the requirements for entering, working, and exiting High Radiation Areas.
- State the administrative and physical controls for access to High Radiation Areas.

Radiation Areas, High Radiation Areas, and Very High Radiation Areas

There are three types of areas we are going to discuss in this Module: Radiation Area, High Radiation Area, and Very High Radiation Area. Each of these types of areas present an exposure risk in which radiation levels could result in an individual receiving a high dose.

A Radiation Area is any area accessible to individuals in which radiation levels could result in an individual receiving a deep dose **equivalent of 5 millirem in 1 hour at 30 centimeters up to 100 millirem in 1 hour at 30 centimeters from the source or from any surface that the radiation penetrates**.

High Radiation Area is any area, accessible to individuals in which radiation levels could result in an individual receiving a deep dose equivalent in **excess of 100 millirem in 1 hour at 30 centimeters from the radiation source or from any surface that the radiation penetrates.**

Very High Radiation Area is any area accessible to individuals in which radiation levels could result in an individual receiving an absorbed dose **in excess of 500 rads in one hour at 1 meter from a radiation source or from any surface that the radiation penetrates.**

Sources of High and Very High Radiation at Argonne

Hot cells: Found in Buildings 205, and 212.

Accelerator facilities: Produce very high radiation when operating. Found in Buildings 203, 211, 212, and 400 (APS Complex).

Irradiators: Radioactive sources in shielded containers. Found in building 202.

X-Ray devices: Pose hazards if safety controls are tampered with during operation. Found in Buildings 202, 205, 212, 223,241, 306 and 440.

Waste storage: Found in Building 306 and subfloors of 331 Shell.

Requirements for High/Very High Radiation Area Workers

Individuals that work in High and Very High Radiation Areas are required, at a minimum, to successfully complete High Radiological Training and the practical exams that are required for High Radiological Worker Training, as well as sign and complete the appropriate RWP and other work control documentation.

Additionally, Health Physics determines the radiological worker's current accumulated dose to ensure the annual/ administrative limits will not be surpassed. The level of HP coverage is determined during pre-job RWP briefing and access points to the area are secured with controlling devices to ensure protection from unauthorized, inadvertent, and potentially dangerous radiation exposure.

Access Controls for High / Very High Radiation Areas

Control methods for access into High and Very High Radiation Areas

- Localized shielding
- Radiation warning indicators
- Locked or interlocked access doors and panels
- Written work procedures
- Health Physics job coverage

It is important to remember:

- Always practice ALARA (As Low as Reasonably Achievable)
- Do not stay in elevated radiation areas longer than necessary
- Know your evacuation points in case of an emergency
- Immediately report any unexpected, dangerous, and/or alarming conditions

Violating Radiological Postings and Access Controls

Workers that violate radiological signs and postings or bypass access controls are putting themselves, and possibly others, at risk. Contact your supervisor or HP if you have any questions about radiological postings or requirements.

Violating radiological signs and postings or bypassing access controls may cause:

- Injury
- Equipment damage
- Excessive/unplanned personal exposure to radiation
- Disciplinary action

MODULE 9 – CONTAMINATION CONTROL

Module Objectives

In previous modules, we discussed the types of radiation and their effects. In this module, we will discuss radioactive contamination and the methods used to control the spread of the contamination. Using proper contamination control practices help to ensure a safe working environment.

Upon completion of this module, you will be able to:

- Define fixed, removable, and airborne contamination.
- Define contamination, high contamination, and airborne radioactivity areas.
- State sources of radioactive contamination.
- State the appropriate action/response for:
  - A spill of radioactive contamination
  - Control of spills
  - Normal methods used for decontamination
- Identify the proper use of protective clothing and the proper use of personnel contamination monitors.
- Identify the requirements for entering contamination and airborne radioactivity areas.

Types of Radioactive Contamination

In previous modules, the basic definitions of the different types of radioactive contamination were discussed. In this module, we will discuss, in somewhat greater detail, the definitions of fixed and removable contamination, and airborne radioactivity.

Fixed contamination is radioactive contamination not easily removed by casual contact. It can be released or removed by grinding, buffing, using volatile liquids, and over time, it may become loose or removable. Fixed contamination can be identified easily. Fixed contamination may be identified with postings, small radioactive materials stickers/labels that indicate fixed contamination, or painted with "Fixed contamination under paint" or similar stenciled on top.

Good contamination control practices should be used while working around these areas which include keeping large/heavy items off the areas, not using chemicals that could "lift" the fixed contamination, avoiding scrapping/grinding in that area, among others. Awareness of these areas, and measures to ensure that fixed contamination does not become loose, are extremely important. Health Physics routinely surveys radiologically controlled areas and appropriately labels fixed contamination when it is discovered.

Removable contamination is contamination that may be transferred by casual contact and spread to other surfaces such as floors, tools, etc. Removable contamination can be in liquid and powder form. Special care should be taken while working with dispersible radioactive material, and it should only be used in designated contamination areas. Health Physics develops Radiological Work Permits (RWP) that establish the hazards that are present and prescribe mitigating factors such as engineering controls, personal protective equipment, control limits, etc. Health Physics personnel should be contacted before new radiological activities occur, or if the scope of an activity changes, to develop an associated RWP.

Airborne radioactivity is removable contamination suspended in air in the form of particles, vapors, fumes, mists, or gases. Air movement can cause removable contamination to become airborne and suspended in air causing a potential internal dose uptake. Health Physics calculates the likelihood of an activity causing airborne radioactivity and applies engineering controls (i.e., hoods, gloveboxes) or additional PPE (i.e., respiratory protection) if this is the case.

Sources and Causes of Radioactive Contamination

Radioactive contamination is simply defined as radioactive material in an undesirable location. As previously discussed, it can be fixed, removable, or airborne contamination. The health concern is the potential to spread to personnel as external contamination or internal contamination from ingestion, inhalation, or absorption. Regardless of the precautions taken, radioactive material will sometimes contaminate objects, areas, and people.

The following are general causes of radioactive contamination:

- Unnecessary contact with contaminated items
- Sloppy work practices while working with radioactive materials
- Poor housekeeping in Contamination Areas
- Leaks from liquid systems containing radioactive atoms
- Airborne radioactive atoms deposited on surfaces
- Damaged or leaking containers, drums etc., designed to hold radioactive material
- Opening radioactive systems without proper control
- Torn or damaged tents, gloves boxes, or other structures designed to hold radioactive material
- Improper usage of step-off pads, change areas, ropes, ventilation, and boundaries

Methods to Control Radioactive Contamination

Every radiological worker should work in a manner as to minimize and confine the spread of radioactive contamination. Controlling contamination minimizes the potential for internal exposure and personnel contamination, and it reduces the likelihood of spreading radioactive materials to undesirable locations.

Some methods to control the spread of radioactive contamination are detailed below. These methods will have to be adjusted based on the form of the material.

Prevention

- Establish work controls
  - Establish clear steps for work
  - Identify hazards in Work Planning and Control

    - Incorporate work controls into RWP with Health Physics
- Create a sound maintenance program
- Use good housekeeping practices
    - Designate areas for waste
    - Keep number of activities in contamination areas limited
    - Cover work areas to minimize clean-up
    - Minimize the number of tools and equipment brought into contamination areas
    - Keep benchtop areas and workspace free of clutter
- Store material (especially liquids) in containers designed to withstand radiation and any solvents
- Liquids should be stored in a secondary container or tray whenever feasible
- Conduct pre-job planning (briefings, job staging etc.; see below)

Engineering Controls
- Ventilation
- Containment (gloveboxes, fume hoods, glove bags, hot cells, etc.)

Personal Protective Measures
- Protective clothing
- Respiratory equipment

Establishing pre-job planning methods before working with radioactivity is best accomplished by:
- Using RWPs, surveys and pre-job briefings to plan your work and procedures (RWPs must be established before new radiological work begins)
- Using mock-ups or similar non-contaminated equipment to practice your work plan
- Staging the work area and the equipment to prevent spread of contamination during the work process
    - Working in trays to contain potential spills
    - Putting down plastic or absorbent material
- Complete understanding the hazards of the job and ensuring that all parties are aware of job parameters

Engineering Controls

Engineering controls are physical design features that are used in order to control the spread of contamination. All radiological work must be evaluated to determine if engineering controls are required for proposed work. Health Physics assesses proposed work and will recommend if engineering controls are needed. If engineering controls are not feasible or do not provide adequate protection, Health Physics may recommend respiratory protection. Establishing these preventive measures must occur BEFORE working with radioactive materials.

Engineering controls include:
- Fume hoods or gloveboxes to handle the radioactivity

- Ventilation systems that maintain Contamination Areas at NEGATIVE pressure relative to outdoors
- Routine maintenance programs for operating systems to minimize failures and leaks that lead to contamination
- Leak and breach repairs completed as soon as identified to prevent a more serious problem
- Ventilation systems that are working properly and as designed

Personal Protective Equipment

It is a requirement to wear some form of personal protective equipment (PPE) when working with radioactive materials here at Argonne. The level of PPE required depends on the conditions of the workplace. Radiological PPE requirements are found on RWPs and will clearly state the type of protective wear that is needed. It is extremely important during job planning to identify all hazards (not just ones radiological in nature). Different PPE may need to be worn due to non-radiological hazards. An example of this would be if you are working with an experiment where there is a fire hazard, you may need to consider flame retardant PPE. If there is no removable contamination concern (i.e., only going into a radiation area), no PPE may be required under that RWP.

A full set of protective clothing at Argonne commonly includes: coveralls, cotton glove liners (optional, and use should be based on worker comfort), two pairs of gloves, shoe covers, rubber overshoes or rubber boots, a hood, and a respirator. Depending upon the radiological conditions, there may be other PPE required, such as rubber or leather gloves, sleeves, aprons, non-permeable alternatives, etc. For most general lab work inside a contamination area, the required PPE would include a lab coat and two pairs of nitrile gloves with no skin exposed. Lab coats used for radiological work at Argonne are not required to be a certain color, though some facilities have designated lab coat colors for work performed in RBAs. In some cases, coveralls without a respirator may be required when kneeling or there are tight spaces in a Contamination Area (CA).

NOTE: This course DOES NOT qualify you to wear respiratory equipment.

In addition to any required PPE, there are some basic guidelines when it comes to accessing or working in all radiologically controlled areas including no eating, smoking, chewing or drinking (drinking may be allowed under certain circumstances when authorized by the Radiological Safety Officer or designee). Wear gloves when handling radioactive material, including encapsulated or sealed sources.

PPE Donning and Doffing

Donning and doffing PPE is an important part of contamination control. If it is done incorrectly, you could end up with contamination being inadvertently spread to your skin or outside of contamination areas. Proper donning and doffing procedures are provided through onsite operator aids. Donning and doffing will be evaluated during the practical portion of this training.

Below are some general considerations when donning and doffing PPE.

Lab Coat

- Check integrity of lab coat
- Do not wear a lab coat that has holes or tears

Gloves

- Before donning gloves, check integrity
- DO NOT blow air into gloves with your mouth to check for holes
- If two sets of gloves are required, consider wearing extended cuff as your inner pair
- It is a best practice to tape inner gloves to lab coat; this helps keep skin from becoming exposed
- Doff outer gloves frequently while working with radioactive materials
- Outer gloves should be doffed into the Contamination Area (CA)
- Be careful not to touch inner gloves with outer gloves when doffing
- Frisk areas of the lab coat that were exposed to the CA (i.e., sleeves, chest area), before doffing

Argonne — HP Operator Aid

Removal of Lab Coat

With Health Physics approval, a different removal sequence may be used depending on the working conditions. The following removal sequence is normally used to remove Lab Coats with gloves and shoe covers when exiting a contaminated area:

1) Remove outer pair of gloves
2) Remove exposed tape
3) Frisk affected areas of a Reusable Lab Coat or dispose of Non-Reusable Lab Coat
4) Remove Shoe Covers while stepping into clean step-off area (if applicable)
5) Remove Lab Coat and return to designated area (if applicable)
6) Remove Inner Gloves
7) Monitor per RWP (Frisk or use Hand and Foot Monitor) before exiting area

RSO Op Aid # 16 20161121

For nuclear facilities only:

FM approval: ____________________

Nuclear facility operator aid #__________

Argonne — HP Operator Aid

Donning a Lab Coat

With a Health Physicist approval, a different Donning sequence may be used depending on the working conditions. The following Donning sequence is normally used to Don Lab Coats with gloves and shoe covers:

1) Gather and check the integrity of the PPE to be used
2) Don Shoe Covers – if required
3) Don the Lab Coat
4) Don Inner Gloves
5) Tape the inner gloves over the Lab Coat sleeve
6) Don Outer Gloves
7) Don any additional monitoring equipment (i.e. Electronic Dosimeter) – if required
8) Don any additional PPE (i.e. 3rd pair of gloves, Work Gloves, Apron, Gauntlets…) – if required

RSO Op Aid # 15 20161121

For nuclear facilities only:

FM approval: ____________________

Nuclear facility operator aid #__________

Examples of Operator Aids

Coveralls:

- Check integrity of coveralls before donning
- If wearing with gloves, don and doff gloves like wearing a lab coat
- Doff coveralls by rolling inside out. Try your best not to touch the outside
- After removing foot from boot portion, immediately step into clean area with that foot
  - Do the same with the other foot
- When making full body entries, request a Health Physics technician (HPT) to be present to perform full body frisk immediately after exiting or proceed on a designated path to the nearest whole-body PCM (Personnel Contamination Monitor) if one is available

Coveralls and a Respirator:

Please note that the "Coveralls and Respirator" information does not apply to the Fire Department Personnel.

- Check integrity of coveralls, gloves, shoe covers, etc.
- Tape all potential skin exposure areas (i.e., tape zippers, inner gloves, and respirator)
- External monitoring devices (i.e., lapel air samplers) should be taped on the outside of coveralls
- Remove additional PPE and external monitoring equipment first
- Remove coverall by rolling inside out (leave respirator on)
- Doff PPE into designated waste bag or drum
- Step onto clean area as you remove shoe covers
- Follow directions given by HPT

Argonne NATIONAL LABORATORY HP Operator Aid

Removing Full Set of PPE with Respirator

With Health Physics approval, a different removal sequence may be used depending on the working conditions. The following removal sequence is normally used to remove a full set of anti-contamination clothing:

1) Remove additional PPE - if used (i.e. Work Gloves, Apron, Gauntlets...)
2) Remove additional monitoring equipment - if used (i.e. Lapel, Electronic Dosimeter)
3) Wipe down respirator – if required
4) Remove exposed tape
5) Remove outer shoe covers
6) Remove outer-most pair of gloves and inner glove tape
7) Remove coveralls by unzipping, removing hood from front to rear, rolling inside out, taking care to touch only the inside of the coverall
8) Remove inner shoe covers as you step into clean / step-off area
9) Wait for smear results and HPT instructions before removing respirator
10) Remove last pair of gloves
11) Remove Respirator after receiving HPT Approval
12) Wait for HPT to perform Whole Body Frisk or proceed to nearest PCM
13) Have HPT perform Smear and Frisk Survey of inside of Respirator

RSO Op Aid # 12 20161121

For nuclear facilities only:

FM approval: ____________________

Nuclear facility operator aid #__________

Argonne NATIONAL LABORATORY HP Operator Aid

Donning Full Set of PPE with Respirator

With a Health Physicist approval, a different Donning sequence may be used depending on the working conditions. The following Donning sequence is normally used to Don a full set of anti-contamination clothing with a Respirator:

1) Gather and check the integrity of the PPE to be used
2) Gather and check any additional monitoring equipment that may be required (i.e. Lapel, Electronic Dosimeter)
3) Don inner shoe covers – if required
4) Don coveralls
5) Don outer shoe covers
6) Don inner gloves
7) Tape inner gloves over coverall sleeves
8) Don outer gloves
9) Don Respirator
10) Pull coverall hood over Respirator and zip coveralls
11) Tape over the coverall zipper and all openings around Respirator
12) Don any additional monitoring equipment (i.e. Lapel, Electronic Dosimeter) and cover with plastic – if required
13) Don any additional PPE (i.e. 3rd pair of gloves, Work Gloves, Apron, Gauntlets…) – if required

RSO Op Aid # 11 20161123

For nuclear facilities only:

FM approval: ____________________

Nuclear facility operator aid #__________

Examples of Operator Aids

Additional Information for the Fire Department Personnel	
Information listed in this section includes general considerations when donning and doffing PPE. Please note that additional requirements, per AFD procedures, may be followed along with this guidance.	In general, the Argonne Fire Department staff will don and doff full turn out gear and follow all AFD procedures when doing so. However, in some circumstances (i.e., investigation mode), AFD staff may be instructed to don lab coat and gloves.

PPE Considerations

Personal protective equipment (PPE), such as coveralls, adds another layer of clothing that may cause heat-related medical issues that need prompt attention.

- Heat Exhaustion: Severe thirst, heavy sweating, pale complexion, extreme weakness, nausea, vomiting, shallow breathing, headache, clammy moist skin, and body temperature up to 102 degrees.
- Heat Stroke: Hot, dry skin, little or no sweating, chills, high body temp, throbbing headache, dizziness, confusion, difficulty breathing, loss of consciousness, rapid pulse.

Prevention of Heat Stress:

- Wear light weight clothing beneath coveralls.
- Drink plenty of fluids before, during, and after heat stress activities.
- Acclimate to the hot environmental conditions prior to a heavy activity.
- Wear light-colored clothing in the sun.
- Rest indoors or in the shade whenever you feel heat stress symptoms occur.
- Contact Worker Safety and Health to evaluate occupational heat stress.

Medical Care for Heat Stress

- Immediately stop work if you experience symptoms of sudden and severe fatigue, nausea, dizziness, or light-headedness.
- Call 911.

Seek Emergency Medical Attention for:

- Heat stroke victims (>102-degree temperature, loss of consciousness, little or no sweating, rapid pulse).

While Waiting for Help to Arrive:

- Bring person indoors or into shady areas, loosen or remove heavy clothing, lay person down and elevate feet, cool down with water, give sips of cool, clear fluids, and monitor temperature. If vomiting, turn person on their side to prevent choking.

For more information, see [LMS-PROC-169](), Control of Occupational Heat Stress.

Response to a Spill of Contaminated Material

Please note that the information contained in this section does not apply to the Fire Department Personnel.

For radioactive spills that are large and pose an immediate safety risk to yourself or other workers, immediately exit the area where the spill is located without attempting to stop or secure the spill. Promptly call 911 to report the spill to the Argonne Fire Alarm Office.

If you are using a cell phone, dial 630-252-1911.

Note: calling 911 from your cell phone, rather than 630-252-1911, may delay response as you will first be routed to the DuPage County dispatch center, which may then either route the call to the Argonne Fire Alarm Office or relay the information to them.

Contamination control's purpose is to help decrease the likelihood of a release of radioactive material; but if you are working and a small spill of radioactive material that stays within designed Contamination or High Contamination areas occurs, remember the **SWIMS** acronym.

If the radioactive spill also contains toxic chemicals or would cause immediate harm to an individual, remove yourself from the immediate area without attempting to stop the spill. Call 911 in abnormal situations and when chemical hazards are present. Always inform dispatch and first responders of **ALL** hazards present, not just radioactive.

- **S**top or secure the operation causing the spill if qualified to do so.
- **W**arn others in the area and notify Health Physics.
- **I**solate the spill area, stop the spill if qualified to do so.
- **M**inimize exposure to radiation and contamination.
- **S**tay in the area until help arrives.

We will focus on the first S and I of SWIMS

Please note that the information contained in this section does not apply to the Fire Department Personnel

Before work with radioactive materials begins, consider the form of the material. Is it solid, a finely milled powder, or a liquid? Depending on your answer as well as the scope of the work being performed, you may want to plan your spill control steps differently.

When working with material of any form ensure that work configuration is well thought out. Glassware, sample holders, etc., should be secured in such a manner that will decrease the probability for a material spill. The way this is accomplished will depend greatly on the work being performed.

For easy clean-up, work with plastic laid down in your workspace.
For smaller scale hood work, use work trays to contain material if there is a spill.

If you are working with powders, consider having water and paper towels available to put over large powder spills. This will help contain the powder especially in high air flow areas. Contain the spread of material by wetting paper towels and placing them on top of the powder. Dampening the powder decreases the ability of the powder to spread.

When working with liquids, make sure you use some type of absorbent material underneath and around your experiment set up when feasible. Work with liquids in spill trays when feasible. At the very least, absorbent material should be available near your workspace.

Verify that materials used in spill response are compatible with the chemicals/compounds you are working with.

The rest of the acronym is self-explanatory. When responding to a spill, depending on the spill, scope of work, equipment, etc., you may not follow the SWIMS in that specific order. Always notify Health Physics when a spill occurs. Health Physics will need to perform various surveys after a spill.

It is also important to note that if the spill and other hazards are severe enough, you should immediately remove yourself from the situation and call 911 without attempting to secure the spill. Only attempt to isolate a radioactive spill if you are not in immediate danger.

Using Personnel Contamination Monitors

As discussed in previous modules, you are required to survey/frisk your hands and feet when exiting a Radiological Buffer Area (RBA). Many RWPs on site require that partial or full body frisks are performed after working in a contamination area, high contamination area and airborne radioactivity area. Be aware that full body frisks, when exiting contamination areas after making a full body entry, should be performed by a Health Physics technician unless a whole-body PCM is available.

Contamination monitors are used to detect radioactivity on personnel and equipment. There are several types of monitors that could be in your area. Hand and foot monitors (various types) and whole-body PCMs have been briefly mentioned before; there could also be a portable contamination monitor issued to your lab.

When using a portable contamination monitor:

- Verify the instrument is in service and has functioning audio mode by turning the instrument on before you begin work. If the portable contamination monitor appears to not be functioning, contact your local Health Physics office.
- Place the portable contamination monitor in a configuration where you can easily survey your hands without touching the monitor (i.e., with probe face facing up). Do this before you begin work.

- Mentally note an average background rate or background audio noise.
- After doffing outer gloves, hover your hand about ¼ inch from the probe face for about 5-7 seconds. Do this with both your palm and back of the hand.
- If there is no increase in counts per minute or audio, then proceed to survey other exposed portions of lab coat.
- Hold probe ¼ inch from surface and move probe slowly. Movement should be about 1-2 inches per second.
- Contact Health Physics if any increase in counts per minute or audio occurs.
- Whole-body surveys with a portable contamination monitor should be performed by a Health Physics technician.

When using a hand and foot monitor or whole-body PCM:

- Verify that the monitor is functioning. Each type of monitor has an interface that will indicate if it is ready and functioning. The exception is manual hand and foot monitors. With these, observe that it is reading a background rate and that the monitor is turned on.
- After working in a contamination area, perform a partial or full body frisk before using the portable contamination monitor (unless there is another process approved by your area Health Physicist).
- If you do not observe a rate increase when doing your frisk, proceed to the exit monitor before leaving the lab.
- Using each type of monitor will be slightly different. In most areas, there are posted operator aids to assist in their use.
- If the monitor alarms, contact Health Physics.

Decontamination of Personnel and Equipment

Decontamination is the removal of radioactive material from locations where it is not wanted. If removable contamination is discovered, typically through scans, surveys, and smears, decontamination is the normal way to remove it. In some cases, economic considerations and radiological conditions need to be considered before decontamination is completed.

Personnel Decontamination

- Use mild soap and lukewarm water **under guidance of Health Physics**.
- More aggressive decontamination techniques may be necessary if soap and water do not work.
- DON'T attempt to decontaminate yourself in order to pass through the hand and foot monitors.
- Take care to not create abrasions or wounds if decontaminating skin.

Equipment Decontamination

- Includes tools, floor, work areas, etc.
- Scrubbing, rad-wash soap, and other methods are used under the supervision of Health Physics.
- Scabbling (removal with high pressure hoses).

- In some cases, decontamination is not possible.

Economic Considerations
- Cost of time and labor.
- May be more cost effective to dispose of as low-level radioactive waste rather than to decontaminate.

Radiological Conditions
- Decontamination process may expose worker to unnecessary radiation dose.
- Decontamination activity may not be in line with ALARA principles.

Additional Information for the Fire Department Personnel
NOTE: Personnel and equipment decontamination will be under the guidance of Health Physics. This slide provides examples of different methods you may be asked to assist with.

Working in Contamination Areas

Contamination, High Contamination and Airborne Radioactivity Areas require special attention from radiological workers. Additionally, the posting for the area will state: Radiological Work Permit (RWP) required for entry.

These areas are posted with yellow and magenta signs, as illustrated in Module 6 – Access Controls and Postings.

When working in Contamination, High Contamination, or Airborne Radioactivity Areas, apply the following safeguards:
- The following basic clothing is required (this is **in addition** to any PPE prescribed by the RWP): closed toe shoes, long trousers over shoe (no exposed skin), tops with ¼ length or longer sleeves and pull back and secure long hair.
- Avoid unnecessary contact with contaminated surfaces.
- Observe all RWP and control point guidelines.
- Ensure equipment, tools, hoses, etc. DO NOT cross in and out of contaminated areas to prevent the spread of contamination. Secure them in some fashion (use tape, clamps, zip ties, etc.).
- Place contaminated materials in appropriate containers when finished.
- Ensure that skin is NOT exposed to contamination; high levels of contamination can cause a significant skin dose.
- Avoid acts that could disturb contamination as it can become airborne.
- Exit immediately if wounds occur or if your PPE is torn, becomes wet, or otherwise compromised.
- Do not smoke, eat, drink, or chew gum.
- Do not put anything in your mouth.
- Do not touch your face with potentially contaminated gloves.

When exiting Contamination, High Contamination, and Airborne Radioactivity Areas, perform the following:

- Avoid unnecessary contact with contaminated items.
- Exit only at the step off pad or designated area when leaving contamination areas after making full body entries.
- Remove protective clothing following posted instructions.
- Survey for contamination (whole or partial body frisk depending on circumstances).
- A whole-body frisk is usually performed by a Health Physics technician in a low dose area, usually away from the step off pad.
- Ensure that all tools and equipment are surveyed before the removal from radiological areas.

Please note, the order of steps may be different depending on what work is being performed and where it is being performed. Always follow instructions given by Health Physics on how to exit contamination areas.

Other Radiological Contamination Controls Found at Argonne

Other types of radiological contamination control may include:

- A non-permeable barrier (usually referred to by its brand name, Herculite), is frequently placed immediately adjacent to posted contamination areas.
- Frisking requirements will be performed as specified by the RWP, Doffing Operator Aid, or at any time when directed by Health Physics personnel.
- For work where radiological contamination levels are not known, but likely to be contaminated, an RWP is required. The work will be under direct observation, and the technician will be empowered to implement required access and exposure control measures.
- Post-job radioactive contamination surveys are conducted as part of the job coverage.

MODULE 10 - RADIOLOGICAL WORK PERMITS (RWPS)

Module Objectives

This module explains the radiological work permits used at Argonne National Laboratory.

Upon completion of this module, you will be able to:

- State the purpose of and information found on Radiological Work Permits.
- Identify the worker's responsibilities and rights in using Radiological Work Permits.
- Recall the information contained in each section of the radiological work permit (RWP).
- Describe and identify the different types of control limits and their function.
- Define the role of hold points.
- Identify the training required to work under the RWP.
- Identify the personal protective equipment (PPE) needed to work under the RWP.
- List the various types of engineering controls that may be specified by the RWP.
- Identify the air monitoring requirements that might be mandated by the RWP.
- Identify the dosimetry requirements of the RWP.
- Recall the Health Physics coverage required to conduct work under the RWP.

The Purpose of the RWP

An RWP is required to conduct work safely in a radiological area. The RWP is a focal point of the ALARA process at the Laboratory, and requires the participation of workers, line management and Health Physics professionals. Higher-level hazards present in a radiological area may warrant an additional review by laboratory management. The ALARA Review Process would begin at this point in order to have additional input for job planning purposes.

As discussed earlier, the development of an RWP is an important step in the WPC process when planning activities that are performed in a radiological area or an activity could produce a radiological area.

RWP Implementation

The RWP form requires completion by Health Physics (either a Health Physicist or Chief Health Physics technician) with the assistance of, and final approval by, the job supervisor before it is posted at the job site. The job supervisor initiates a Work Control Document (WCD), which includes an accurate description of the proposed work, and includes the building and room where the activity will be performed, as well as an assessment of the radiological hazards and other hazards present.

The WCD is then forwarded to Health Physics who completes the RWP, often with the assistance of the job supervisor to discuss the job scope and details, which may include radiological concerns, dose and contamination control limits, pre-job briefing requirements, protective requirements (dosimetry, protective clothing, Health Physics coverage, etc.) and special engineering controls (ventilation, shielding, etc.).

If necessary, Health Physics technicians will survey the work area to determine the actual dose rates and contamination levels. This information is then recorded on the RWP or a separate survey map may be attached.

After Health Physics understands the nature of the proposed work and the radiological conditions, they can specify the special requirements or instructions to be included on the RWP such as, dosimetry, protective clothing or equipment, and additional instructions for radiological safety and ALARA considerations.

Once Health Physics completes the RWP, it is signed for approval by both the job supervisor/PIC and Health Physics. The RWP is now ready for review and signature for everyone performing activities covered by the RWP. A copy of the RWP is ready for posting at the job entrance site.

Worker's Responsibilities

RWPs are required for entry into radiological areas. The original copy to read and sign is normally located in the Health Physics office. Ask your Health Physics personnel or job supervisor. In some cases, a copy will be posted near the job site. Always ensure you are signed in on the most up to date RWP by contacting your local HP office.

As a worker it is your responsibility to read, understand, agree to comply with the instructions on the RWP, and to complete the required training. Your signature acknowledges your agreement with the RWP. If a revision is made to the RWP, your review and signature are again required.

One of the protective requirements found in the RWP, that is often misunderstood, is the control limit. A control limit is the limiting value for individual dose, collective dose, dose rate, contamination level, or other radiological condition listed in an RWP.

These limits are set for ALARA considerations in order to avoid an overexposure or potential spread of contamination. If a radiological condition is encountered that exceeds a control limit, this means that something unexpected may have arisen and that the current radiological controls may not be sufficient. Therefore, if a control limit is exceeded, work is halted and concerns are addressed prior to work continuing.

When reviewing an RWP, if you do not understand a control limit or any aspects of the RWP, or if you see anything that is inaccurate, it is your responsibility to contact your supervisor or Health Physics.

The RWP Header

The first section of the RWP contains basic information about the RWP such as:

- The RWP permit number
- A description of the work covered by the RWP

- The person in charge (PIC) of the work being conducted under the RWP and the date of their approval of the permit
- The Health Physicist (HP) who is overseeing the radiation protection of the work and the date of their approval of the permit
- The division conducting the work
- The Argonne National Laboratory Radiological Safety Officer and the date of their approval of the permit (if required)
- The ALARA review type (If needed)
- The effective date and the expiration date of the permit

RWPs expire within one year or less. RWPs can be designated as "general" or "job-specific."

A general RWP is defined as an RWP which may be used for long durations for multiple locations, using numerous work planning and control documents and procedures that cover routine work activities.

General RWPs are briefed annually.

A job-specific RWP is defined as an RWP which may be used for a specific job or task including high risk radiological work that includes detailed step-by-step instructions or activities that are planned and executed in a short time.

Job-specific RWPs are briefed quarterly at a minimum.
RWPs may be briefed more frequently if a job is intermittent or particularly hazardous.

Permit 2017-TRAIN-702PRF

Description of Work:	TRAINING USE ONLY - Full body entry into a high contamination area requiring a respirator		
Person in charge (PIC):	282973 Rojas, Christopher Alex	**Health physicist (HP):**	241457 Meadows, Erin Elizabeth
PIC Approval:	Jan 4, 2018, 2:09 PM	**HP Approval:**	Jan 3, 2018, 8:14 AM
Division:	HSE	**Rad Safety Officer (RSO):**	58921 McCormick, Diep Quan
		RSO Approval:	
Effective date:	01/04/2018	**Expiration date:**	1/4/19

Locations

The Locations section of the RWP specifies in what areas the work may be conducted.

Locations

Building	Room	Location	Comments
202	A338		TRAINING AREA

Cross References

If the work under an RWP requires a work control document (WCD) permit or other authorizing document, it must be listed in the Cross Reference section. Radiation survey documentation is also referenced in this section.

Cross References

Type	Cross Reference No	Comments		
Procedure Number	HPP 9.2	Contamination Control Requirements		
Procedure Number	HPP 3.0	Performing Radiological Surveys		
WCD Task	99998	Inspect tools for damage		

Workplace Conditions

The Workplace Condition section of the RWP lists essential information regarding the area in which the work is being conducted. The radiological posting of the area, the types of radionuclides expected, the physical description of the work area (e.g. bench top, fume hood, glovebox) and the types of radiation emitted (e.g. alpha, beta-gamma) are all listed in this section. In addition, this section allows for the inclusion of any miscellaneous information that may be pertinent.

Workplace Conditions

Type	Value	Comments		
Posting/Expected Conditions of Primary Work Space(s)	High Contamination Area			
Primary Radionuclides of Concern	Beta-gamma emitters (nuclides with decay modes other than alpha emission or spontaneous fission), except Sr-90 and others noted above			
Primary Radionuclides of Concern	Transuranics, Ra-226, Ra-228, Th-230, Th-228, Pa-231, Ac-227, I-125, I-129			
Primary Work Space(s)	Bench Top			
Primary Work Space(s)	Room			
Principle Radiation(s)	Alpha			
Principle Radiation(s)	Beta-gamma			

Known Radionuclides

This section allows the listing of the exact radionuclides that will be part of the work if known.

Known Radionuclides

Description	Comments		
Americium-241			
Caesium-137			

Control Limits

The Control Limit section of the RWP is one of the most important. If a control limit in this section is exceeded, work must be halted and the need for revision of the RWP must be discussed with the area HP.

Following are the control limits that may be listed on the RWP:

- Collective dose
- Individual dose
- Maximum dose rate
- Removable alpha contamination
- Removable beta contamination

Control Limits

Type	Value	Unit	Comments		
Max γ @ 30.0 cm	5.0	mR/h	Not for use in a Radiation Area		
Removable α	20000.0	dpm/100cm²			
Removable β	1000000.0	dpm/100cm²			

Hold Points

Hold Points are conditions that must be met in order for work to continue. Typical hold points are the requirement of an HP tech to take a radiological reading, the types of decontamination techniques allowed, or ensuring that protective measures, such as covering surfaces with plastic, are in place before proceeding with work. The actions required by hold points can help to ensure that control limits are not exceeded.

Hold Points

Hold Point		
Consider wiping down items/area if contamination levels are found to be 15000 dpm alpha and 700000 dpm beta.		
Place herculite or equivalent in the work space.		

Required Training

The mandatory training level required to perform the work covered by the RWP is listed in the Required Training section. Except for cases where an individual with General Employee Radiation Training (GERT) is escorted in lieu of Radiological Worker I training, the RWP system will track whether the person is current in their required training.

If the person is out of compliance, it will be signaled in the workers section of the RWP. If their training lapses during the RWP's active period, a notification email will be sent to the PIC and HP. It is incumbent on every individual to ensure that they have the required training before conducting work on an RWP.

This section also looks at respirator qualifications and bioassay status.

Below is a summary of required training based on radiological area type:

- Radiation Area- Radiological Worker I, Radiological Worker II, High Radiological Worker or GERT with escort
- High Radiation Area-Radiological Worker II or High Radiological Worker
- Contamination Area-Radiological Worker II
- High Contamination Area-Radiological Worker II

All levels of training, except GERT, have an associated practical factors exercise. The radiological worker II practicals vary by required personal protective equipment (PPE) level and must be repeated every 2 years. Radiological worker I has a practical that only needs to be completed once.

Required Training

Description	Comments		
Radiological Worker Training Level II			
Radiological Worker II Training - Practical Exercise / Full Dress-out			
Bioassay Participant	Automatically added by dosimetry selection		
Bioassay Protocol Review	Automatically added by dosimetry selection		
Resp. Protection - Air Purifying Respirator	Automatically added by control selection		

Personal Protective Equipment (PPE)

This section stipulates the PPE that is required to perform the tasks authorized by the RWP.

The comments portion of the PPE section could include clarification about required PPE or make certain PPE conditional depending on the conditions of the workspace (i.e. non-permeable PPE when working with liquids).

Personal Protective Equipment (PPE) Controls

Description	Comments		
gloves - nitrile (2-pair, tape inner layer to sleeves)			
respirator, full-face HEPA			
shoe covers (2 pair)			
coveralls, all openings taped			

Engineering Controls

The Engineering Controls section details the mechanisms or equipment required to mitigate the radiation hazard. It can include everything from required shielding, the use of plastic sheeting, or the requirement that the work be done in a fume hood or glovebox.

Engineering Controls

Description	Comments		
containment - plastic sheet on work surfaces			

Administrative Controls

The Administrative Controls section specifies administrative requirements of the permit such as the type of briefings and surveys required prior to and after the completion of the work.

Administrative Controls

Description	Comments		
worker contamination survey - whole body	Required upon removal of coveralls.		

Air Monitoring

The Air Monitoring section specifies the type of sampling required when needed to monitor for airborne radioactivity.

Air Monitoring

Description	Comments		
Lapel			

External and Internal Dosimetry

The External and Internal Dosimetry section of the RWP details the type of dosimeter that must be worn including the requirement for an electronic (alarming) dosimeter and what its alarm set points must be set to. It also lists any requirements for the workers to be part of an internal bioassay program.

External & Internal Dosimetry

Comments			
Beta Gamma Dosimeter			
Bioassay Participant			

Health Physics Coverage

The Health Physics Coverage section of the RWP mandates the type of Health Physics oversight the work will require.

The following are the different types of Health Physics coverage that may be required, and their definitions.

- **Continuous:** Monitoring of the radiological conditions and status of a job by an assigned Health Physics technician who, at a minimum, can communicate with workers, is aware of work activities, and is able to direct, stop, or pause work as conditions warrant.
- **Start of Job:** Monitoring of the radiological conditions and verifying that the RWP requirements are met at the beginning of a job or task.
- **End of Job:** Monitoring of the radiological conditions and verifying that the RWP requirements are met at the end of a job or task.
- **On-Call:** Capable of being contacted via phone or pager to provide assistance verbally or to be present at the job site as needed.

Health Physics Coverage

Description	Comments		
At least two Health Physics Technicians continuously at worksite (one in hot zone and second in support zone)			

Workers

The Workers section of the permit lists all the workers briefed on the RWP and allowed to perform work under its guidance. Next to each worker's name is the date they were briefed on the permit requirements, and whether their training is up to date.
If a worker with GERT is being escorted at all times by a trained radiation worker, their name will not be listed, and their training status will not be tracked by the system. However, these individuals must still sign an RWP signature sheet and follow the requirements of the RWP.

Workers

Badge	Name	Briefed	Training Needs		
240954	Henry, Michael James	01/08/2017	All required training is up-to-date.		
282973	Rojas, Christopher Alex	01/08/2017	ESH118 - Resp. Protection - Air Purifying Respirator 		

LESSONS LEARNED

Scenario 1: Nuclear Facility Workers/Health Physics

Introduction: On January 4, 2010, in building 200 MA/MB cave area, an Argonne waste mechanic was discovered to have reportable contamination on his personal clothing after sampling legacy mop water in a nuclear facility. This event could have been avoided by following and adhering to written work control documents, radiological work permits, and following pre-job planning and pre-job briefing methodology.

Discussion: Approximately 10-15 gallons of radioactive contaminated mop water was originally placed in a 55-gallon drum following cleanup of a spill in 2001, then later over- packed into an 85-gallon drum when the original 55-gallon drum was found to be leaking. Sampling of the legacy mop water was needed to determine proper disposal in accordance with the Waste Management requirements.

Prior to sampling, the sampling methodology was discussed during the Plan-of-the-Day meeting. The sampling method was agreed upon; however, a sampling plan was not formally written and tested, as the waste specialist was not available to assist. In addition, there was no job-specific pre-job brief performed.

The work was to be performed under a "walk-in" style hood with an opening for personnel access and material to be sampled. However, the hood was not large enough for an 85- gallon drum and other factors made the movement of the drum difficult. Therefore, the assistant facility manager (AFM) decided to sample the drum outside the hood with the agreement of the waste mechanics and HP tech.

With some difficulty, the drum lid was eventually removed and set aside. The sampling device was used to attempt to obtain a sample numerous times by the AFM, the waste mechanics, and the HP tech without success. Finally, the AFM abandoned use of the sampling device, and, using a gloved hand to hold the sample bottle, dipped the sample bottle into the mop water to obtain a sample. The sample bottle was wiped dry, placed in a plastic bag, and set aside for transport to the Analytical Chemistry Lab.

Upon leaving the contaminated area, the AFM and the waste mechanics detected contamination on their shoe covers, gloves, lab coats, and one pant leg.

1. What are appropriate times to exercise stop work authority?

   a. When work cannot be performed as planned
   b. When work cannot be performed in the planned location
   c. When the equipment designated for a job is deficient and/or unsuitable and cannot be used
   d. All of the above

Solution: The correct answer is D. STOP WORK authority is both the right and obligation at the discretion of all employees when they perceive a dangerous situation, or when the work cannot be performed with the equipment and procedures as planned.

2. RWP and Work Control Documents are not required when a supervisor directs a change of work scope in the field?

   a. True
   b. False

Solution: The correct answer is B. A change in scope should be discussed with Facility Management and Health Physics. Subsequently, the RWP and/or Work Control Documents may have to be changed with briefings and/or Plan-of-the-Day discussions to communicate the change(s).

3. Prior to a high-risk job being performed, what should be included in preparation?

   a. RWP, Work Control Document(s), and job-specific pre-job brief
   b. Review and testing of the work plan and equipment to be used
   c. Walk-down or review of the job site with respect to the work to be performed
   d. All of the above

Solution: The correct answer is D. All the items mentioned are important to the preparation of high-risk jobs.

4. What should all workers know to lessen the chance of this happening again?

   a. Always obtain written, reviewed, and approved work directions, not just verbal directions
   b. Perform a pre-job brief as close as possible to the actual work location to ensure worker understanding of plans, procedures, hazards, and controls

c. Stop Work Authority is an important safety factor and should be exercised when a job cannot be performed as planned
d. All of the above

Solution: The correct answer is D. All work in a radiological area should be formalized and documented on an RWP and WCD, with a pre-job brief to discuss the work. In addition, Stop Work Authority is always an important factor of safety management.

Scenario 2: Waste Mechanics/Health Physics

Introduction: In August of 2011, a Nuclear and Waste Management (NWM) mechanic and a Health Physics technician (HPT) became contaminated because the protective clothing (PC) used was not designed for unexpected damp conditions encountered.

Discussion: Three Nuclear and Waste Management (NWM) mechanics and two Health Physics technicians (HPTs) were tasked with repackaging contact-handled transuranic (CH- TRU) waste in a room with equipment specifically designed for such a task. The repackaging consists of sorting through bags of radioactively contaminated trash to remove prohibitive items such as batteries, lead, chemicals, light bulbs, and any other materials that would cause the waste to be "mixed," which would make the waste both a chemical hazard and radioactive hazard.

Along with a full set of protective clothing, gauntlets were being used on their forearms as an extra barrier of protection from any loose/dry contamination that they may come in contact with. However, the material being processed was damp, which was a change from the dry material that was previously being sorted before this entry. Since this was a change in work scope, the operational personnel should have exercised Stop Work Authority to review their PC requirements.

The personnel finished their work, removed their PCs, and exited the room in their scrubs (undergarment clothing). The NWM Mechanic and HP technician set the alarm off while processing through the personnel contamination monitor (PCM) and were found to be contaminated on their forearms.

The NWM foreman informed the operations manager and area Health Physicist of the incident. During a subsequent fact-finding meeting, the cause of the contamination leaching through the protective clothing was determined; therefore, a change from Tyvek gauntlets to impermeable plastic gauntlets was made.

1. A review in protective clothing requirements should be performed when changes in working conditions (such as finding water/damp conditions) occur.

    a. True
    b. False

Solution: The correct answer is A. Keep in mind that changes in work conditions should always prompt reconsideration of proper protective clothing.

2. What should the workers have done when damp conditions were encountered?

    a. Been more alert to changing conditions and stopped the work
    b. Used fans to dry the damp conditions
    c. Continued to work and discuss the change in conditions later
    d. All of the above are correct

Solution: The correct answer is A. If damp conditions were not planned for, then their Protective Clothing (PC) is probably not designed for damp conditions. The routine PCs are water-permeable making them more comfortable to wear.

3. Why didn't the Tyvek gauntlet stop the contamination?

    a. The material was not a good shielding for gamma emissions
    b. If the Tyvek gauntlet is permeable to water, then it is a pathway for contamination dissolved in the water to leach through the gauntlet
    c. The Tyvek gauntlet was not a barrier for dry airborne contamination
    d. The alpha particles passed through the material and contaminated the worker's forearms

Solution: The correct answer is B. The normal Tyvek Protective Clothing (PC) is not designed to protect in damp or wet conditions because the water permeable material is much more comfortable to wear on a routine basis.

4. Radioactive waste items with chemical hazards should be segregated from other regular radioactive waste.

    a. True
    b. False

Solution: The correct answer is A. If waste materials contain more than one hazard, it is considered a "mixed waste," which greatly increases the cost of disposal. So the reason for segregation is twofold: not to mix two hazards together if it can be avoided, and to separate true mixed waste from radioactive waste and dispose of it separately.

Scenario 3: Custodial

Introduction: In January of 2012**,** an Argonne custodian entered a lab which was controlled for radiological purposes, removed low-level radioactive waste that was marked as radioactive material, and placed the bags in a non-radiological dumpster. The radiological waste was later retrieved and retraining performed.

Discussion: Radioactive waste and general waste (i.e. office wastebasket contents) must be kept separate. Both have different waste streams for eventual off-site disposal, with the cost of the radioactive waste being significantly higher. Radioactive waste is generated and stored across the site in locations clearly marked with yellow and magenta signs, and should only be handled by trained and experienced personnel. Contrary to this, a custodial worker who was relatively new to the building entered a lab which was controlled for radiological purposes and collected four radiologically labeled and unsealed radioactive waste bags. He placed the open rad bags in his regular trash gurney and disposed of the gurney contents into a large dumpster.

When the four rad bags were later spotted in the dumpster, the dumpster was NOT clearly labeled for radiological material and covered to protect it from the rain and snow. The hauling company was then notified not to retrieve the dumpster until further notice. The bags containing radioactive waste were collected and the outside of the bags surveyed. The bags of radiological waste were then disposed of properly.

As a follow-up, the custodian was interviewed and was surveyed along with his vehicle. Even though no contamination was found, he was given a bioassay kit to ensure that no ingestion or inhalation of radioactive material occurred while handling the radioactive waste.

1. How is waste separated and disposed of at Argonne?

    a. Radioactive waste and general office waste are disposed of in different containment vessels for off-site shipment to different locations
    b. General office waste and radioactive waste can be mixed together and disposed of in the same dumpster
    c. Recyclable waste and general office waste are disposed of together and separated at the local landfill
    d. All of the above are correct

Solution: The correct answer is A. Radioactive waste is far more expensive to dispose of than ordinary office trash, so only contamination trash should be disposed of as such. Subsequently, trash containing radioactive material should not be sent to general landfill sites as clean trash is.

2. Radioactive trash and general office trash (radiologically clean) is always segregated for different means of disposal from Argonne.

    a. True
    b. False

Solution: The correct answer is A. Radioactive waste is far more expensive to dispose of than ordinary office trash, so only contamination trash should be disposed of as such. Subsequently, trash containing radioactive material should not be sent to general landfill sites as clean trash is.

3. Which of the following most likely indicates that trash contains or could potentially contain radioactive materials?

a. Yellow and magenta radiation bags
b. Clear bags with labeling and markings such as: “Caution, Radioactive Materials”
c. Trash in controlled areas that require personnel to frisk upon exit
d. All of the above are correct

Solution: The correct answer is D. Both the yellow and magenta coloring and the words “Radioactive Material” are clear signs for the potential for presence of radioactive material. In addition, anything in controlled areas that require personnel to frisk is always suspect for radioactive contamination.

Scenario 4: Sealed Source Users

Introduction: On September 28, 2011, two Radiological Control Technicians (RCTs), working at the Brookhaven National Laboratory in New York, were transporting a lead pig containing a Cesium-137 sealed source onsite. The pig tipped over during transport and radioactive contamination from the source was spread to the vehicle and RCTs. The subsequent spread of radioactive contamination to the parking lot, facility rooms, an employee’s hand and shoes, and even another employee’s personal auto could have been prevented. Fundamental radiation safety practices and procedures were overlooked leading to this incident.

Discussion: At 9:30 am, a pig containing a radioactive source was placed on the floor between the driver and passenger seats in a company cargo van for vehicular movement between buildings onsite. While in transit to the work location, the lead pig and 265 microcurie Cs-137 sealed source tipped over onto the driver’s side floor of the van. RCT-1 (driver) immediately righted the pig and handed the sealed source to RCT-2 (passenger), who placed it on the floor on the passenger side. At 10:00 am the source was removed from the van and placed back into the source storage locker in building 923.

At noon, RCT-1 went to lunch as a passenger in a personal auto. Later that day, RCT-1 used the company van for two hours to complete other work activities. At the end of the day, RCT-1 noticed that there was an elevated radiation reading on a survey meter in the van and investigated the cause. He checked for contamination and found it on the van floor, his hands, and his shoes. He donned gloves, removed his shoes, and locked and secured the van. He notified his supervisor.

A review of the event indicated that the source was leaking prior to September 28, and contamination was spread to the van and RCTs when the pig tipped over and rolled. However, the causes leading up to the event include:

- There was a broad misinterpretation of the requirements for packaging and vehicular movement of sealed sources.
- The source was not tested for leakage of contamination since July 22 when all the sources in the area received their semiannual leak test.
- A survey for contamination was not done at the earliest opportunity upon removal of the source and pig from the van. The spread of contamination would then have been found and confined to the immediate area.

Note: Here at Argonne, radioactive material is transported by the Material Control and Accountability (MC&A) group with the radiological assistance of Health Physics (HP).

1. If something potentially contaminated (sealed source or its container) falls, a survey for loose contamination should be performed on the surfaces that the item came in contact with.

    a. True
    b. False

Solution: The correct answer is A. If there is potential for contamination on a surface or item, then a survey should be performed during or after the job is complete.

2. If radioactive material is being transported between buildings at Argonne, you can transport it in your personal vehicle.

    a. True
    b. False

Solution: The correct answer is B. Radioactive items should never be transported in a personal vehicle. The transport of radioactive material at Argonne is done by the Material Control and Accountability (MC&A) group with radiological surveys performed by Health Physics.

3. The groups that assist in the packaging and transport of radioactive material here at Argonne are:

    a. Industrial Hygiene (IH) and Material Sciences Division (MSD)
    b. Material Control and Accountability (MC&A) and Health Physics (HP)
    c. Physics (PHY) and Biosciences (BIO)
    d. None of the above is correct

Solution: The correct answer is B. The transport of radioactive material at Argonne is done by the Material Control and Accountability (MC&A) group with radiological surveys performed by Health Physics.

Scenario 5: Irradiator/Radiation Generating Device Users

Introduction: On March 22, 2010, a technician working at the Idaho National Lab (INL) entered an irradiator room while a radiation beam was present, contrary to visual alarms. He received a dose of 990 mrem to his right extremity. His electronic dosimeter indicated a whole-body dose of 1.3 mrem.

Discussion: A technician was performing an exposure of an instrument. After the test was complete, the tech needed to retrieve the instrument. He pushed the return button on the irradiator control console which should have returned the 1250 curie Cs-137 source to the shielded position and stopped the radiation beam. However, contrary to the RWP, he did not check the control panel indicators and computer display, and was unaware that the source remained stuck in the exposed position. When the technician approached the door, the red flashing "Source Exposed" lights remained illuminated on the panels above the door leading into the room. The tech unlocked this door and proceeded into the room, thinking that some residual activation would be setting off the alarms. He had an electronic dosimeter with him which featured an audible response along with dose rate measurement capabilities.

When inside the irradiator room, the technician approached the instrument and proceeded to grab it, placing his right hand into the high radiation beam as he did. When the beam contacted his hand, the radiation “scatter” or reflection from his hand increased the dose rate to his electronic dosimeter on his chest making it alarm. Simultaneously, his supervisor (outside the room) heard the instrument response, noticed that the "Source Exposed" light above the door was still on, and directed the technician to leave the room.

1. What human performance errors were identified for this incident?

    a. The technician had become over confident when working with the irradiator
    b. The technician assumed the Cs-137 source would drop back down into the shielding container as it always had in the past
    c. The technician did not pay attention to the warning lights
    d. All of the above

Solution: The correct answer is D. Complacency is always an issue in every industry (i.e. getting weary of doing the same routine over and over again). We must always pay attention to warning signs, lights and sounds to be alert of changing conditions.

2. Attention to and adherence to which of the following would prevent radiological incidents, like a radiation overexposure?

    a. The Radiological Work Permit (RWP)
    b. Warning lights and alarms
    c. Radiological postings and labels
    d. All of the above

Solution: The correct answer is D. Complacency is always an issue in every industry (i.e. getting weary of doing the same routine over and over again). We must always pay attention to warning signs, lights and sounds to alert of changing conditions, and periodically read RWPs and WCDs to refresh ourselves if we have forgotten what they contain.

3. Ignoring radiological postings and warning lights may result in an unnecessary radiological exposure.

    a. True
    b. False

Solution: The correct answer is A. Complacency is always an issue in every industry (i.e. getting weary of doing the same routine over and over again). We must always pay attention to warning signs, lights and sounds to alert of changing conditions.

Scenario 6: Building Maintenance/Health Physics

Introduction: On February 23, 1999, at the Idaho National Engineering and Environmental Laboratory (INEEL), a radiological control technician's shoes became contaminated with Cs-137. He had walked through water that had become contaminated when it leaked into the facility through contaminated ductwork.

Discussion: The technician was conducting a routine weekly radiation survey of a fan room and noticed that the radiation readings were higher than those documented in a previous survey. Because of the higher readings, he exited the fan room, performed a personal survey, and detected approximately 2,000 dpm beta-gamma contamination on the soles of both shoes. He then called operations support personnel for assistance, and they roped off the area. Radiological control technicians performed follow-up surveys of the fan room and measured up to 23,900 dpm of beta-gamma contamination on the floor.

The technician became contaminated and contamination was spread as a direct result of water intrusion. Investigators determined that the water came from melting snow that leaked through an open penetration in the side of the building, along ductwork inside the building, and into the ductwork at a split seam. They determined that the water had accumulated on the floor of the fan room but were unable to determine the exact point where water leaked out of the ductwork. It was determined that the water became contaminated from legacy contamination in the ductwork. The technician had noticed water on the floor but did not think that it was unusual and stepped in it. Facility personnel were unable to decontaminate his shoes. The facility manager directed facility personnel to issue a work package to decontaminate the fan room, seal the penetration, and locate and repair any leaky ductwork joints.

1. Puddles of water on the floor in an area that is controlled for radiological purposes can mean which of the following?

    a. Piping from a radioactively contaminated system has leaked
    b. Rainwater has leaked into contaminated ductwork, which has leaked onto the floor
    c. A contaminated floor drain has backed up and pushed water up onto the floor
    d. All of the above are possibilities

Solution: The correct answer is D. Any water puddles should be avoided, cordoned off, and checked by Health Physics personnel as soon as practical.

2. Which of the following conditions contributed to the cause of this incident?

    a. The ductwork contained legacy contamination

b. The ductwork was not water-tight
c. The technician did not think water on the floor was an unusual occurrence
d. All of the above

Solution: The correct answer is D. All of these factors contributed to the problem. If even one factor was missing, the contamination incident would have been avoided.

3. What other problems might be caused by water intrusion?

    a. Damage to safety-related equipment
    b. False alarms due to electrical short circuits
    c. Costs to clean up and repair damage
    d. All of the above

Solution: The correct answer is D. All of the listed problems could occur due to water damage. That is why it is important to inspect and maintain facilities where radioactivity or other hazardous materials are present.

Scenario 7: Researchers/HP

Introduction: On July 11, 2011, a container breach occurred when unexpected pressure ruptured the primary and secondary containment of an experiment containing uranium nitrate/Mo-99 solution resulting in a shoe contamination from stepping in the solution that spilled onto the floor.

Discussion: An employee of the Chemical Science and Engineering Division was performing an irradiation of 2L of uranium nitrate (pH=1) solution spiked with 5 mCi of Mo-99. The uranium nitrate solution was in a 3.6 L glass container with a Bakelite cap with a Teflon liner, surrounded by a secondary container made of PVC. Both containers were intended to confine the liquid with no appreciable pressure increase; therefore, a tray underneath the experiment was assumed to be sufficient if leakage occurred.

According to the post-run re-entry requirements for both the Work Planning and Control document and RWP, Health Physics must take dose rates at the entrance to the cell prior to anyone else entering the room. At 9:15 am on July 12, 2011, a Health Physics technician (HPT) supporting the experiment performed the post-run dose rate measurements. As the HPT took dose rates, the Chief HPT (CHPT) noticed that there was yellow liquid in the tray positioned underneath the target table. The CHPT immediately asked the HPT to step away from the target table and asked the LINAC operator to enter the cell to assist in determining where the yellow liquid was from. The LINAC operator realized that both the primary and secondary container had failed during the irradiation, as a great increase in pressure occurred during the irradiation burst the inner glass and secondary PVC containments. The yellow liquid on the floor was the uranium nitrate solution. The HPT took a wipe of the liquid, and then all staff backed out of the room. The HPT's work shoes were found to be contaminated with 255,000 dpm/100cm^2 beta direct, and 150,000 dpm/100cm^2 beta removable. Whole-body frisks indicated no contamination present on CHPT, HPT, and LINAC operator.

1. Puddles of water on the floor in an area that is controlled for radiological purposes can mean which of the following?

    a. Piping from a radioactively contaminated system has leaked
    b. Rainwater has leaked into contaminated ductwork, which has leaked onto the floor
    c. An experimental containment has failed, leaking contaminated solution
    d. All of the above are possibilities

Solution: The correct answer is D. Any liquid puddles in a radiological area should be suspect for contamination and avoided, cordoned off, and checked by Health Physics personnel as soon as practical.

2. Which of the following conditions contributed to the cause of this incident?

    a. The failure of primary and secondary containment
    b. The bursting of the container overshot the tray that the experiment was placed in
    c. The technician did not notice the solution on the floor
    d. All of the above

Solution: The correct answer is D. All of these factors contributed to the problem. If even one factor was missing, the contamination incident would have been avoided.

3. What are examples of containment of radioactive material?

    a. Sealed glass jars or tubes
    b. PVC tubing
    c. Tray to contain any drips or minor spills
    d. All of the above

Solution: The correct answer is D. All of the containment types listed are routinely used for contamination control purpose.