Cardinal Health™

RADIATION SAFETY TRAINING

Course Objectives

After completing this training, the learner will be able to:

- Identify the different types of radiation.
- Radiation and Risk
- Apply and identify how to use time, distance, and shielding to minimize radiation exposure. ©
- Understand the purpose of a radiation dosimetry badge.
- Describe the uses and different types of radiation survey meters and counting equipment.
- Understand radioactive material ordering, storage and disposal procedures.

Regulatory Overview

Hospital and Clinics must follow Federal and State regulatory standards as well as internal policies and procedures as set in the license conditions.

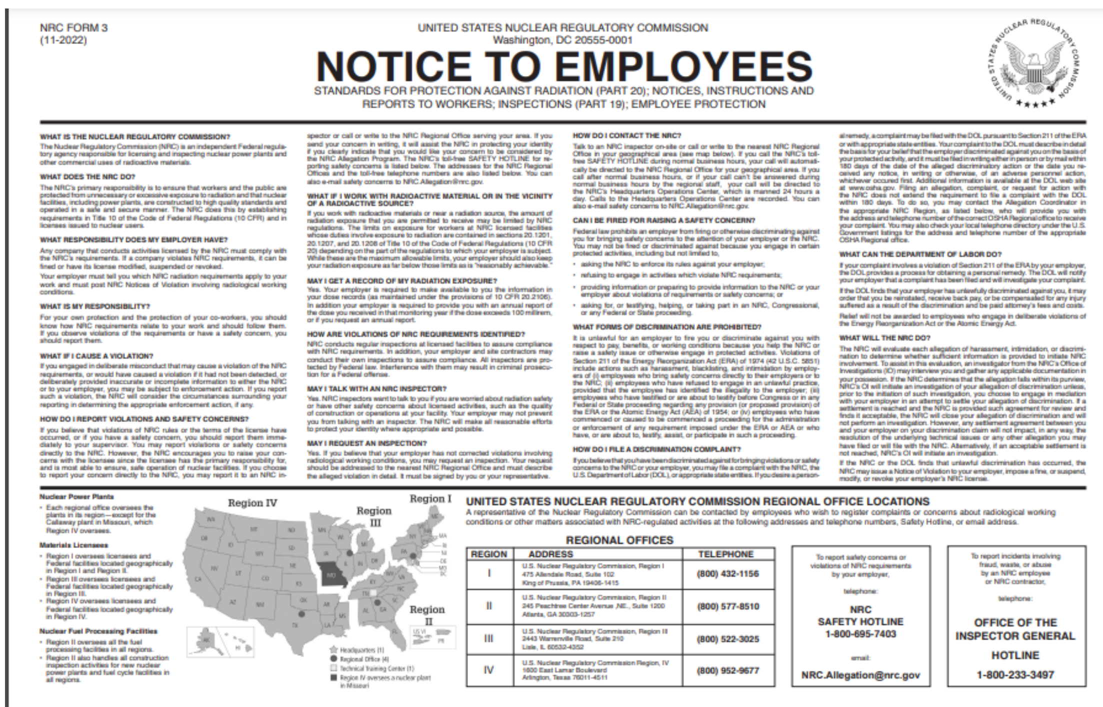
Agreement State and Nuclear Regulatory Commission (NRC) mandate rules and regulations for the clinical and research use of radioactive materials and machines that produce radiation. Agreement State, will meet or exceed regulations set by the NRC.

There is a clear path of authority for the Licensee to follow when regulating the use of radiation in any form, which are:

- Follow regulations set by your State or the NRC.
- Follow policies that are set by the Radioactive Material License, in accordance with state and NRC regulations.
- Retain Record as required by regulations.

Notice to Employees

The Notice to Employees is a formal, legal notice that must be posted in each Department and in areas where it may be seen by employees. The Notice states the employer's and employees' responsibilities when working with radiation or around radiation sources. The notice also provides a means for a worker to contact the State or NRC, if the worker feels endangered by the work environment. In every case, the worker should contact the Radiation Safety Officer first.



NRC FORM 3
(11-2022)

UNITED STATES NUCLEAR REGULATORY COMMISSION
Washington, DC 20555-0001

NOTICE TO EMPLOYEES

STANDARDS FOR PROTECTION AGAINST RADIATION (PART 20); NOTICES, INSTRUCTIONS AND REPORTS TO WORKERS; INSPECTIONS (PART 19); EMPLOYEE PROTECTION

UNITED STATES NUCLEAR REGULATORY COMMISSION REGIONAL OFFICE LOCATIONS

A representative of the Nuclear Regulatory Commission can be contacted by employees who wish to register complaints or concerns about radiological working conditions or other matters associated with NRC-regulated activities at the following addresses and telephone numbers, Safety Hotline, or email address.

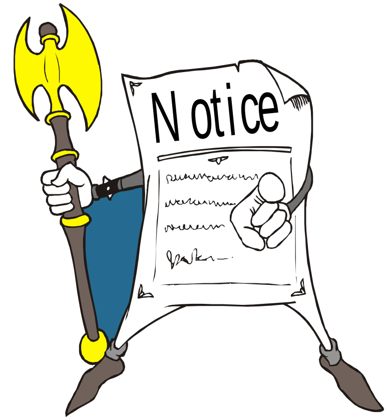
REGIONAL OFFICES

REGION	ADDRESS	TELEPHONE
I	U.S. Nuclear Regulatory Commission, Region I, 475 Allendale Road, Suite 102, King of Prussia, PA 19406-1415	(800) 432-1156
II	U.S. Nuclear Regulatory Commission, Region II, 245 Peachtree Center Avenue ,NE., Suite 1200, Atlanta, GA 30303-1257	(800) 577-8510
III	U.S. Nuclear Regulatory Commission, Region III, 2443 Warrenville Road, Suite 210, Lisle, IL 60532-4352	(800) 522-3025
IV	U.S. Nuclear Regulatory Commission Region, IV, 1600 East Lamar Boulevard, Arlington, Texas 76011-4511	(800) 952-9677

To report safety concerns or violations of NRC requirements by your employer,
telephone:
NRC SAFETY HOTLINE
1-800-695-7403
email:
NRC.Allegation@nrc.gov

To report incidents involving fraud, waste, or abuse by an NRC employee or NRC contractor,
telephone:
OFFICE OF THE INSPECTOR GENERAL HOTLINE
1-800-233-3497

Notice to Employees (cont.)



Employer Responsibilities are:

- Apply regulations.
- Make regulations available.
- Provide a safe work environment for using RAM

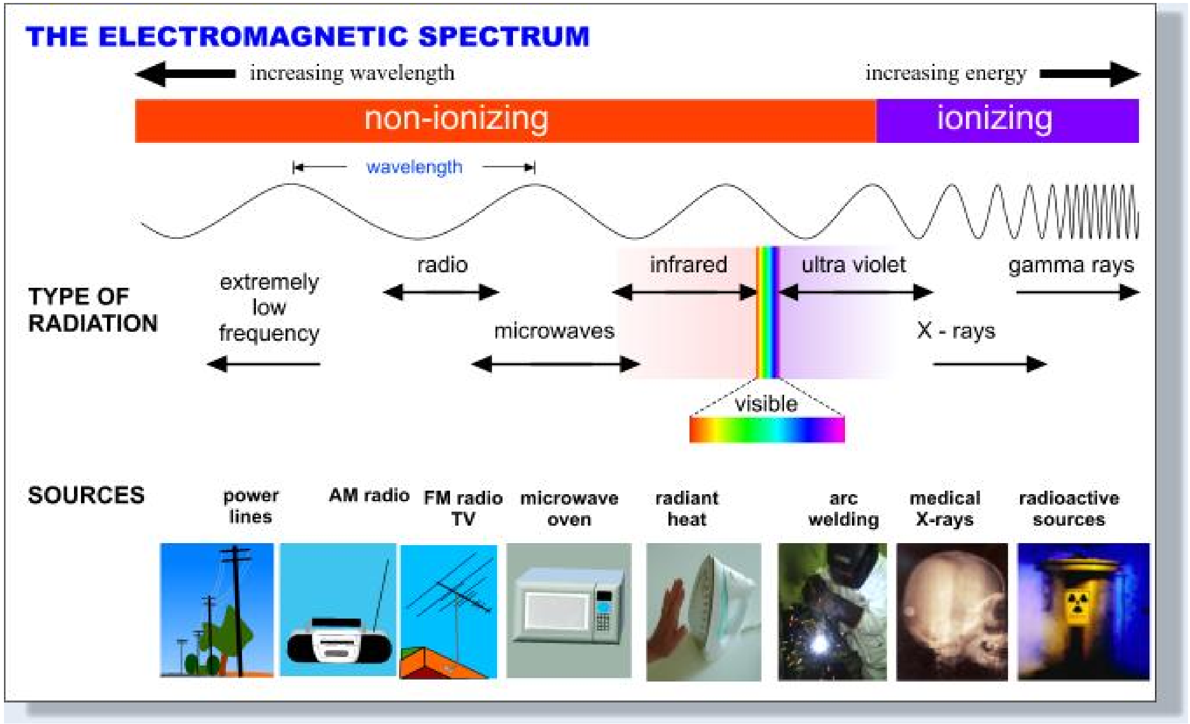
An Employee’s Responsibility is to:

- Become familiar with procedures.
- Observe requirements for your protection.
- Observe provisions for your co-workers protection.

Radiation Defined

What is radiation?

- Radiation energy can be emitted in either a wave or particle form.
- The energy can be either ionizing or non-ionizing.
- Radiation can be emitted from either materials or machines.



Radiation Energy

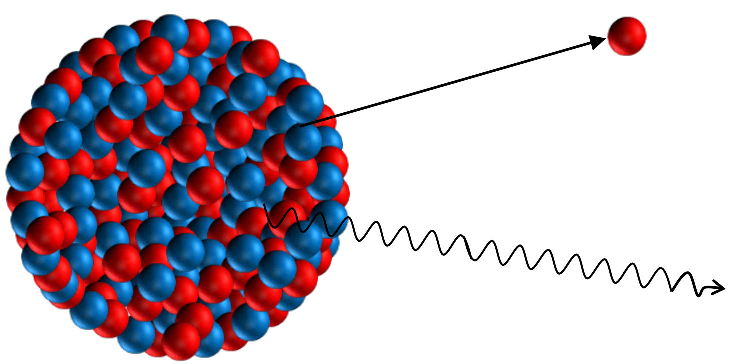
Radiation from materials arises from unstable atoms striving to become stable by releasing their extra energy. The energy is released in either the form of a wave or a particle.

Types of Waves

- x-ray
- gamma ray

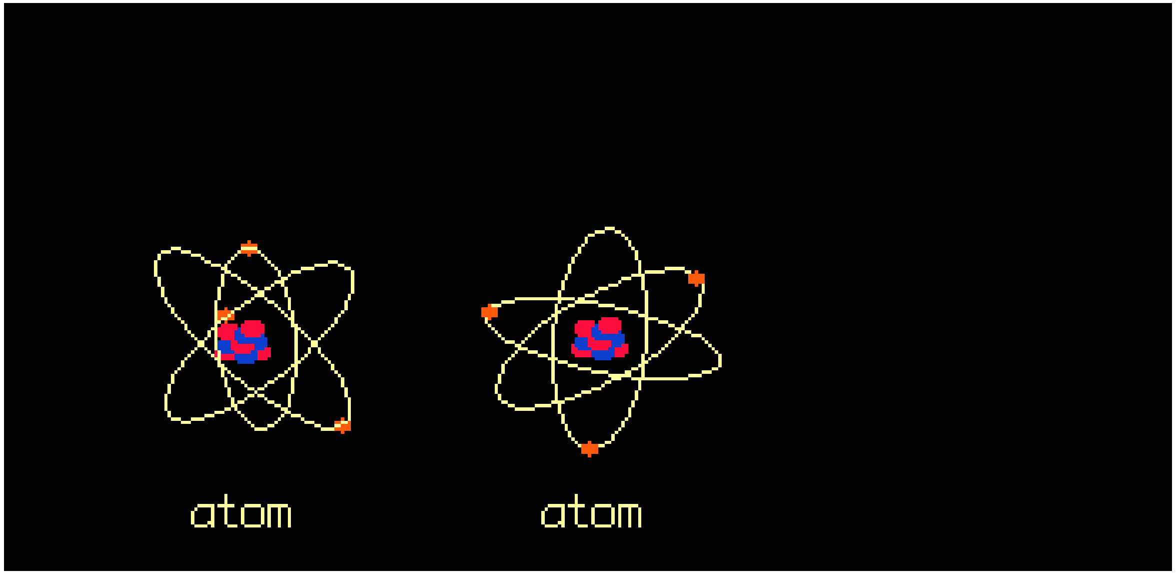
Types of Particles

- alpha
- beta
- neutron



Ionizing Radiation

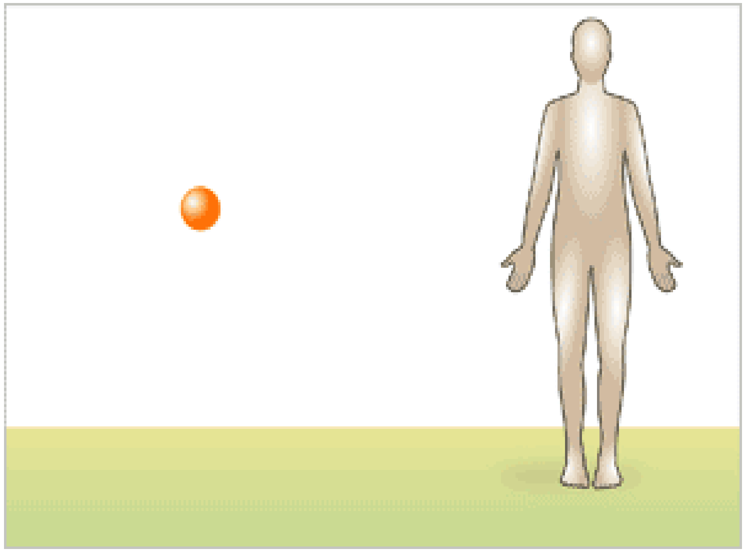
If the energy of the wave or particle is great enough it can deposit energy in neighboring atoms resulting in the removal of electrons. This leaves the atom with a net charge.

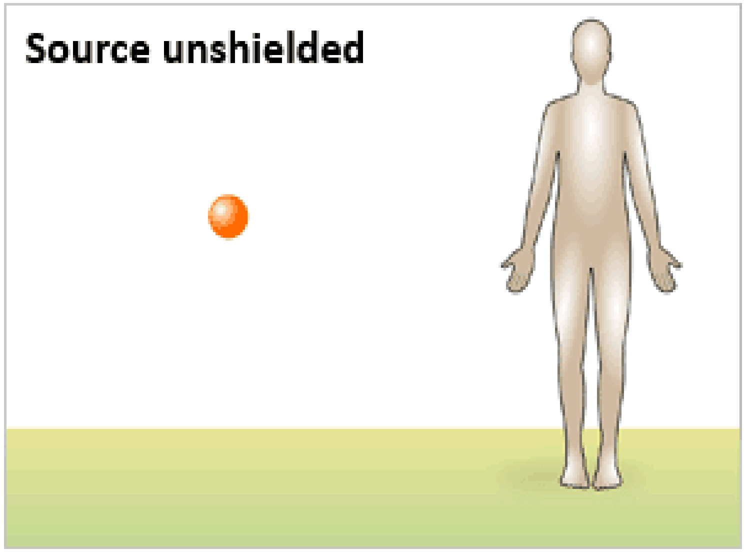


Radiation Contamination

Contamination - The deposition of radioactive material in any place where it is not desired and particularly where its presence may be harmful both internal and external.

Exposure to a radiation producing machine cannot result in radioactive contamination.



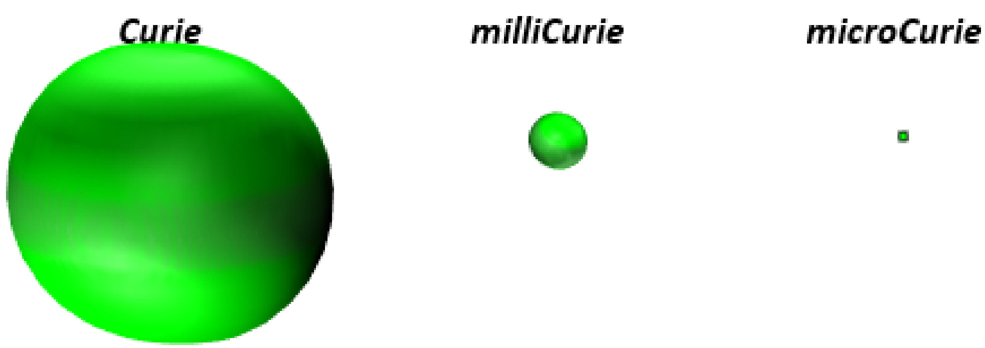


Radiation Activity

The number of nuclear transformations occurring in a given quantity of material per unit time. Radiation activity is expressed as the rate of radioactive decay (Number of disintegrations per unit time, i.e. dps).

<u>Units</u>

- *Curie (Ci) = Standard - used in the United States*
- *Becquerel (Bq) = 1 dps - SI, System Internationale*
- *1 Curie = 37 GigaBecquerels = 37 x 10^9dps*

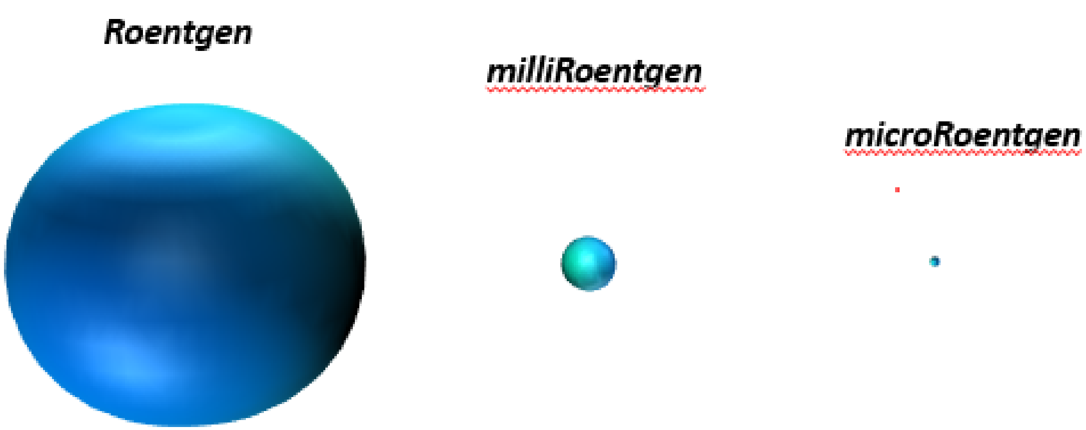


Radiation Exposure in the Air

<u>Units of Exposure in Air</u>

The Roentgen (R) is a special unit of exposure for x and gamma rays. One roentgen equals 2.58×10^{-4} coulomb per kilogram of air.

$$1\ R/hr = 10^3 mR/hr = 10^6\ \mu R/hr$$



Radiation Dose Units

Rad: A unit for measuring absorbed energy from radiation (absorbed dose). One rad is equal to an absorbed dose of 100 ergs/gram.

SI units: 1 Gray (Gy) = 100 rads

Radiation	Quality Factor
Gammas and X-rays	1
Beta particles	1
Alpha particles	20
Neutrons	10

An exposure of 1 Roentgen results in an absorbed dose of 0.87 Rad.
For practical purpose 1 Roentgen = 1 rad = 1 rem

Linear Energy Transfer (LET): The effectiveness of radiation in producing damage is related to the energy loss of the radiation per unity path length. Generally the greater the LET in tissue, the more effective the radiation is in producing damage.

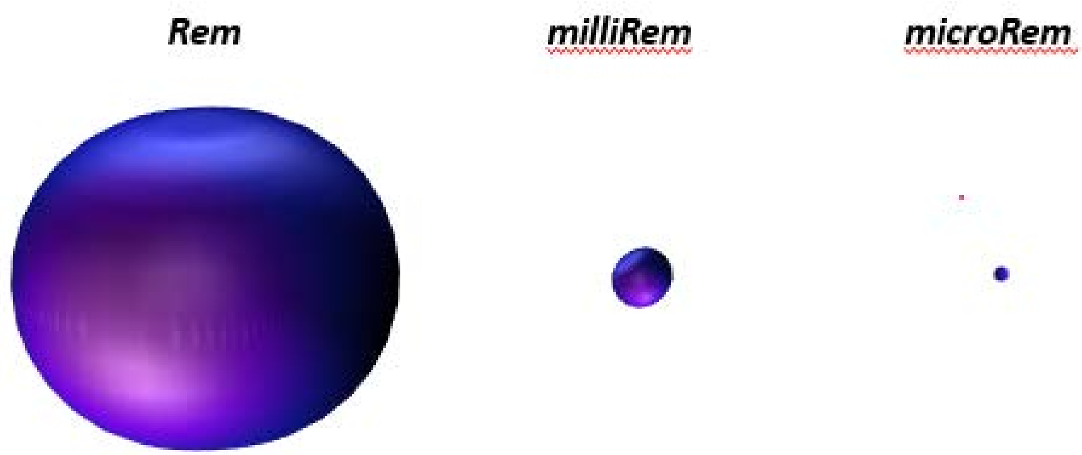
Quality factor (Q): An LET dependent factor by which absorbed doses are multiplied to obtain a comparison for the biological damage producing potential of various types of radiation, given equal absorbed doses.

Radiation Dose Units (cont.)

<u>Dose Units</u>

Rem (Roentgen Equivalent in Man): A unit for measuring biological damage from radiation; a dose equivalent. The absorbed dose (Rad) of specific types of radiation multiplied by the quality factor to arrive at the dose equivalent (Rem = Rad x Quality Factor)

SI units: 1 Sievert (Sv) = 100 Rem



Radiation Risks and Effects

- Early scientists determined that radiation was a useful tool, but it could also hurt you.
- Radiation can cause burns and cellular damage if used or applied incorrectly.

In 1906 Bergonie and Tribondeau established a “law” between radiosensitivity and cell proliferation.

Cells are more radiosensitive if they:

- Have a high mitotic rate (rapidly dividing)
  - Rapidly dividing cells are less likely to correctly repair damage prior to cell division than cells that divide slowly.
- Normally undergo many divisions (long mitotic future)
  - Mitotic future: long - bone marrow, short – brain and bone
  - Damage to a cell that is no longer dividing is not passed on to future generations and does not affect the production of this type of cell.
- Are functionally undifferentiated (non-specialized)
  - Undifferentiated cells: bone marrow and base of villi in intestines- through subsequent divisions produce cells with specific functions.

Radiation Risks and Effects (cont.)

Biological Effects of Radiation

Radiation interacts with the body at the molecular level. Primary molecules of concern are protein molecules of the cell structures, DNA, RNA, and water. The damage produced by radiation can be either direct or indirect.

- ***Ions and free radicals cause indirect damage (stochastic)***
  - Ions and free radicals produced by radiation can interact with DNA.
  - Damage caused by the free radicals can lead to chromosome aberrations.

- ***Direct affects of radiation (deterministic)***
  - Cells and organelles can be damaged from ionizing radiation.
  - Radiation can directly effect DNA by damaging bases and the cross linkages between the bases. Damage can also occur by creating single or double strand breaks in the DNA molecule.

– The effects of direct and indirect damage can lead to cell death.

Radiation Risks and Effects (cont.)

Biological Effects of Radiation

▪ After cells are damaged by radiation, the cells will try to repair themselves. Various factors effect whether cell repair will be successful.

- **Amount of damage (energy)** – The greater the energy deposited, the greater the damage done. If a cell suffers too much damage, it will not be able to repair itself.
- **Location (radiosensitivity)** – Cells highly sensitive to radiation will suffer more damage and are less likely to be able to repair themselves.
- **Mitotic state (dividing)** –Damage at certain points in the cell dividing cycle may be more detrimental to the cell than at other points.
- **Mitotic future (number of divisions)** – Cells have a set number of replications. Damage done after a large number of divisions, may leave the cell unable to replicate.
- **Period of exposure (acute, chronic)**. Cells are less likely to be able to repair themselves from a large (acute) dose creating a large amount of damage at one time compared to a chronic dose causing only a small amount of damage over an extended period of time.

Radiation Risks and Effects (cont.)

High Level Acute Exposures

Acute Exposure – large dose received in a short period time.

Exposure Reading	Radiation Effects
0 - 25 Rem (0 – 0.25 Sv) 5 Rem (0.05 Sv) 25 Rem (0.25 Sv)	No detectable effect (subclinical) Annual whole body limit Effects detectable by chromosome analysis
> 25 – 100 Rem (0.25 – 1 Sv)	Blood changes
>100 – 200 Rem (1 – 2 Sv)	Skin reddening, temporary sterility, temporary hair loss, nausea, and vomiting
450 Rem (4.5 Sv)	$LD_{50/60}$ – eventual death of 50% of population
300 – 1000 Rem (3 – 10 Sv)	Vomiting blood production reduced
1000 – 5000 Rem (10 – 50 Sv)	Failure of GI system. Fatal within two weeks.
> 5000 Rem (50 Sv)	Nervous system failure. Death within days.

Radiation Risks and Effects (cont.)

<u>Pregnancy Risks</u>

Natural Risks

Pregnancy risks from natural causes

- It is estimated that 5 – 8 % birth abnormalities happen at birth or develop later in life due to natural causes.
- About 20 – 30% of miscarriages or still births (known pregnancies) occur from natural causes

Radiation Risks

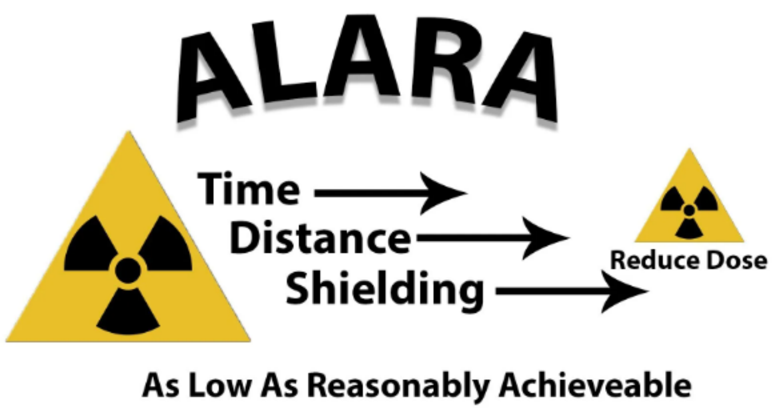
The increased risk from the exposure to radiation.

- Exposure to radiation can cause genetic effects to the fetus. The increased risk from radiation exposure to the fetus is 0.01% per Rem or 0.00001% per mRem received.
- First trimester is the most critical since rapid cell growth of the fetus is occurring.

Radiation Protection

<u>ALARA</u>

The principle of ALARA is used in designing procedures and equipment for radiation protection. ALARA is an acronym for “As Low As Reasonably Achievable”. This means that every effort should be made to keep exposures from ionizing radiation as far below limits as possible. This principle takes into account both technological and economical factors in reaching this goal.



Radiation Protection – ALARA

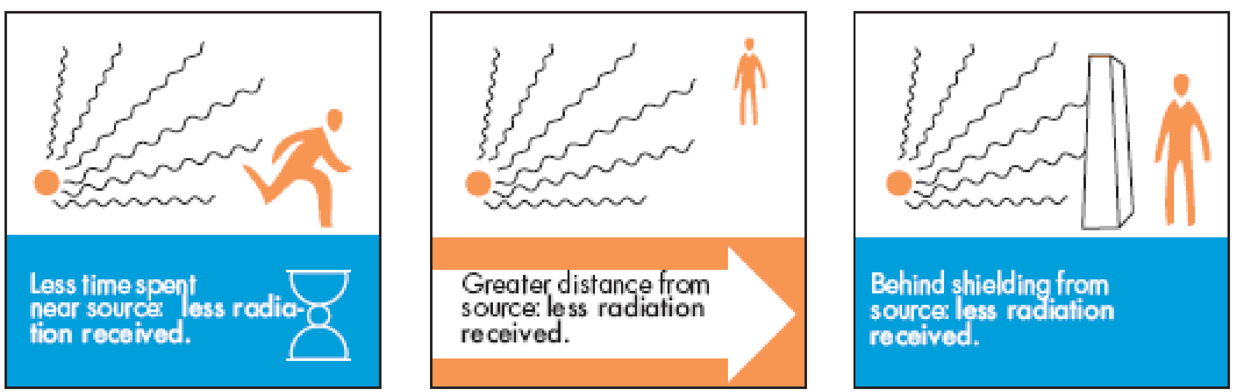
__Radiation Protection__

External Protection

The 3 main factors that effect exposure to radiation are **time**, **distance**, and **shielding**. Adjusting these 3 factors can reduce unnecessary exposure to an individual.

Internal Protection

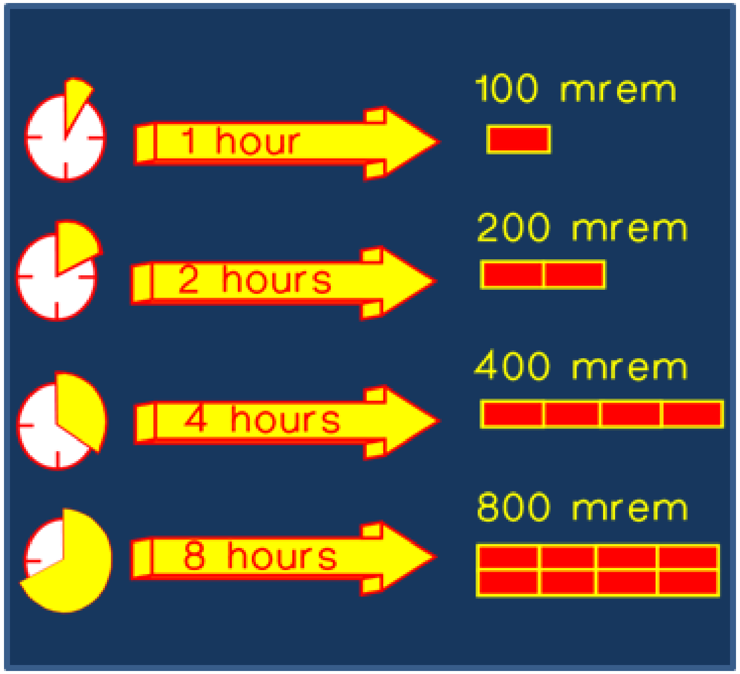
Following general lab safety procedures can reduce one's risk of taking in radioactive materials either through absorption, ingestion, inhalation, or injection.



ALARA – Time

Time

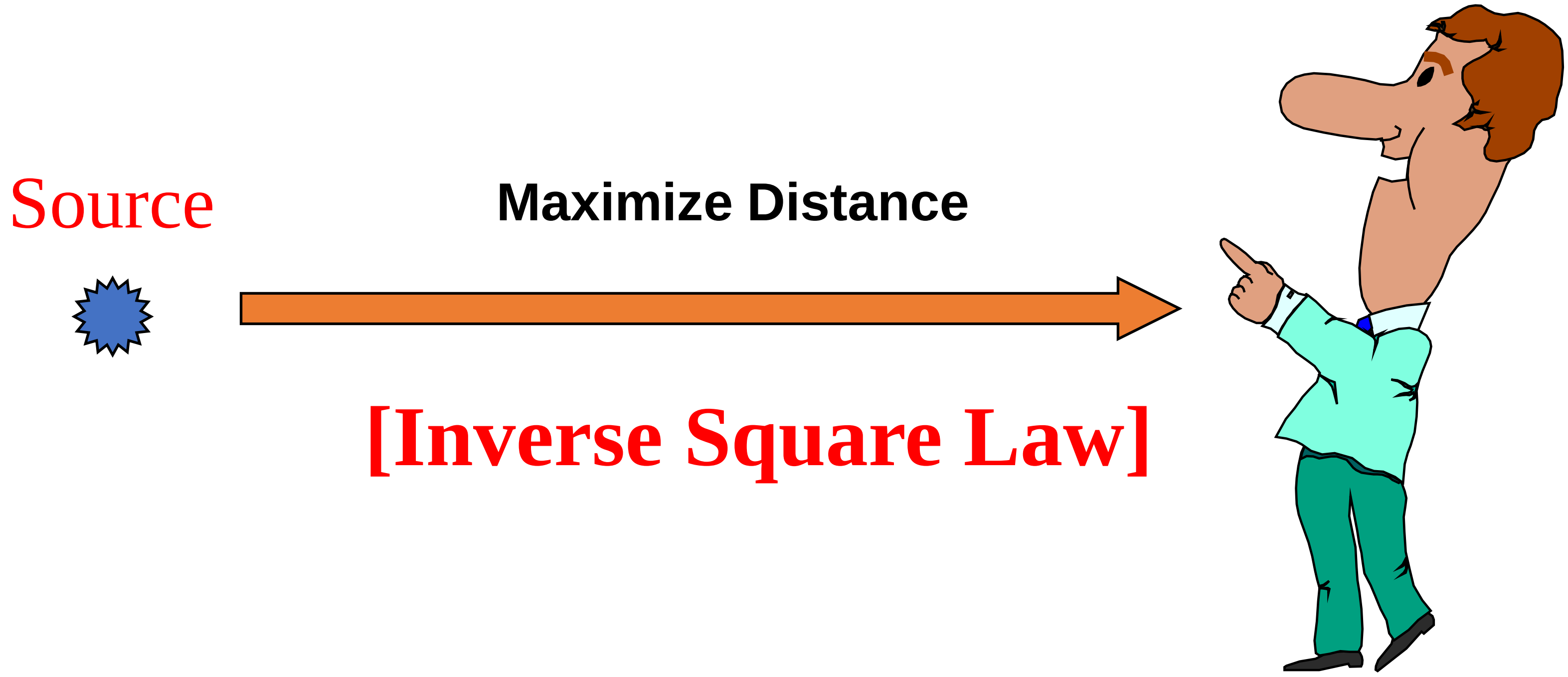
Minimizing the amount of time near a radiation source reduces the exposure. Work should not be rushed in order to reduce the exposure time. This can lead to mistakes causing the task to take longer, therefore, increasing the exposure time.



ALARA – Distance

__Distance__

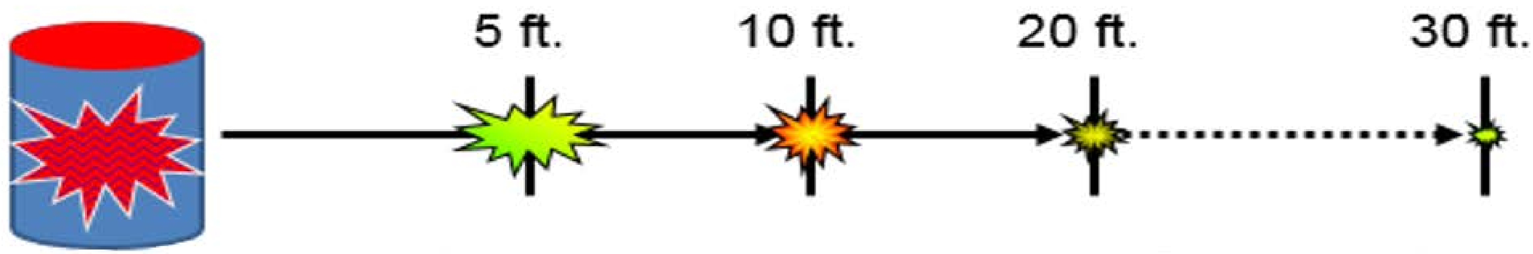
Increasing the distance from the source, will reduce the exposure. The change in exposure rate can be calculated using the inverse square law (Intensity = $1/d^2$). Doubling the distance between the source and oneself will reduce the exposure by a factor of 4.



ALARA – Distance (cont.)

Distance Protection Factor

At 1 ft of the source the dose rate is 1000 mR/hr. As the distance increases the dose rate drops to 40 mR/hr at 5 ft. and 1.1 mR/hr at 30 ft.



I = Intensity D = Distance

$I_1D_1^2 = I_2D_2^2$

$(1000\ \text{mR/hr})(1\ \text{ft})^2 = (I_2)(5\ \text{ft})^2$

$$\boxed{\frac{1000}{25} = 40\ \text{mR/hr}}$$

$I_1D_1^2 = I_2D_2^2$

$$I_2 = \frac{I_1D_1^2}{D_2^2}$$

* 1 mR = 0.01 mSv

$I_1D_1^2 = I_2D_2^2$

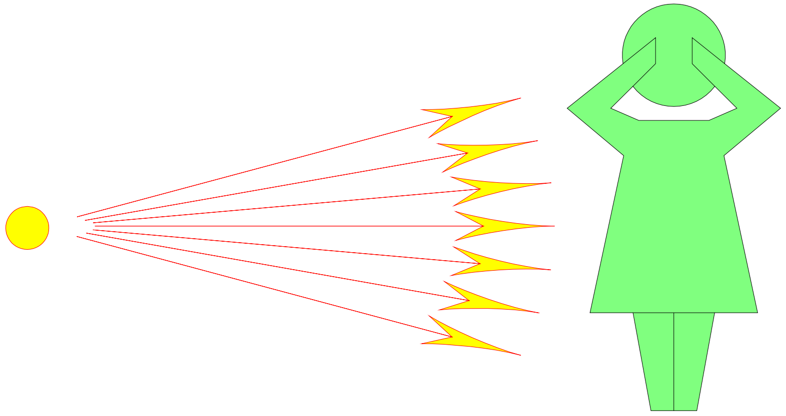
$(1000\ \text{mR/hr})(1\ \text{ft})^2 = (I_2)(30\ \text{ft})^2$

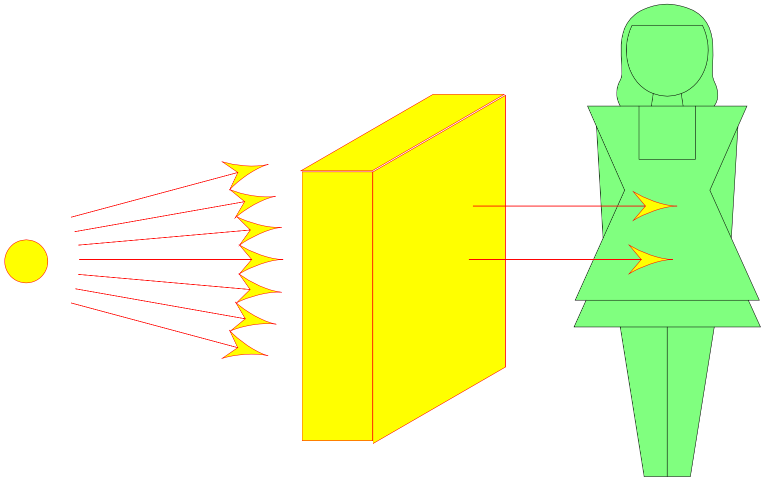
$$\boxed{\frac{1000}{900} = 1.1\ \text{mR/hr}}$$

ALARA – Shielding

Shielding

Shielding helps reduce an individual's exposure from a radiation source by blocking some or all of the radiation. Choosing an appropriate shield can reduce the radiation exposure.

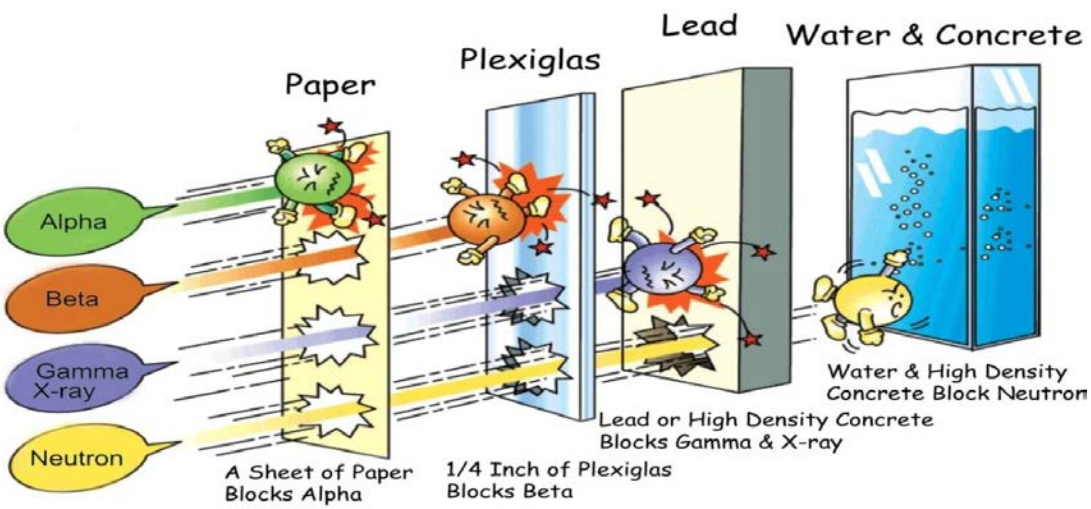




ALARA – Shielding (cont.)

Shielding Materials

Shielding for a radioactive source is dependent on the type of radiation emitted. Not all shielding materials sufficiently block each type of radiation. Typically, the more penetrating the radiation, the higher the density shield required to block the radiation. Plexiglas blocks beta particles, while higher energy x-rays and gamma rays require a denser medium such as lead. Lead is widely use in Nuclear Medicine/PET



Safe Handling Procedures

- During an inspection, the inspectors will look closely at these performance-based procedures.
- Wear gloves and protective clothing (e.g., lab coat) when working with radioactive material in any form.
- Clearly label containers holding radioactive materials with the words "Caution: Radioactive Material" and the radiation symbol.
- Work with radioactive materials over absorbent paper and/or trays to contain contamination.

Radiation Protection – Safe Handling

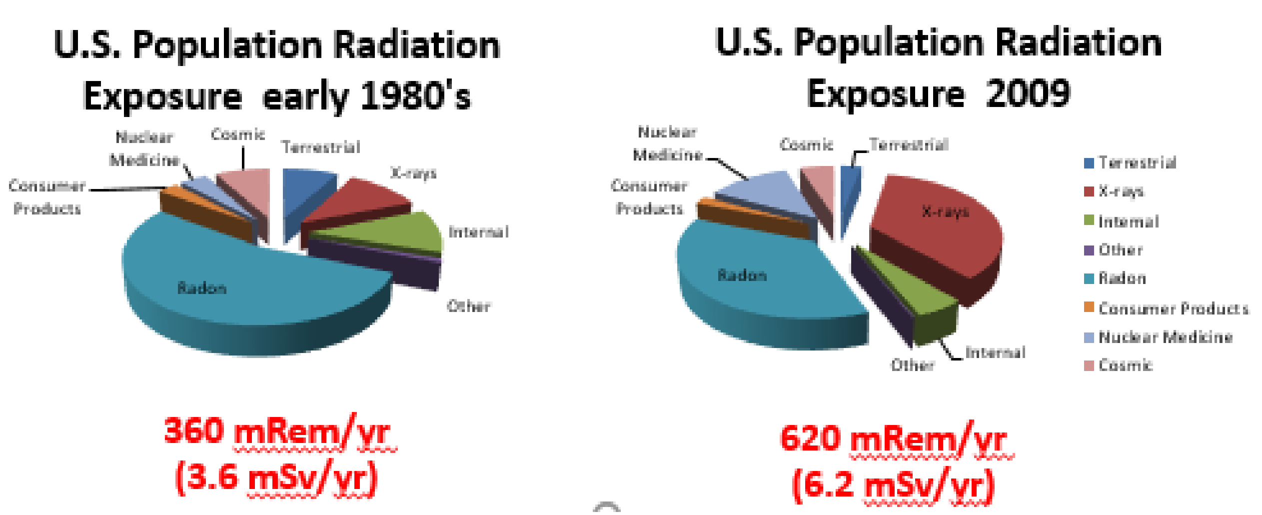
- Use appropriate shielding to keep the dose rate as low as reasonably achievable.
- Never leave radioactive material unattended unless it has been secured against unauthorized removal.
- Monitor during and after procedure to ensure that exposure rates are kept low and that the work area has not become contaminated. Decontaminate any contaminated areas.
- Notify RSO and AU immediately when responding to patient emergencies or death. Please follow your internal policy regarding patient release after radiation treatments/procedures

Radiation Protection – Signage

Posted signs notify staff and other personnel of radioactive materials in a room. Staff should use caution when entering a room that is posted for radiation use.

Radiation Exposure

The average amount of radiation exposure received has increased over the last 20 years. In 1987, NCRP Report 94 published an average exposure of 360 mRem/yr. In 2009 that value increased to 620 mRem/yr. The large increase is due to the increased use of radiation in medical procedures. It is not, however, uncommon for any of us to receive less or more in a given year.



Annual Exposure Limits

The annual exposure limits are established by the NRC and intended to prevent and limit the effects of radiation exposure. Proper precautions should be conducted to ensure individuals stay below these limits. Below are the occupational radiation limits. Dose to individual member of public of the public must be below 2 mrem in any hour and below 100 mrem in a year

	mRem	mSv
Whole Body	5,000	50
Extremities	50,000	500
Minors	500	5
Fetus*	500	5

*Note: Fetal exposure limit is restricted to the gestation period. All other doses are annual limits.

Personnel Monitoring

Personnel monitoring is how the Radiation Safety Officer tracks your annual exposure to radiation while working with or around radiation. A dosimeter or radiation badge monitors your exposure.

What is a dosimetry badge?

A radiation dosimetry badge is a small hexagonal badge that is equipped to determine the estimated exposure to scatter or direct radiation, while working in a radiation area.

Who determines who wears the badge?

Radiation dosimetry badges are assigned by the Radiation Safety Officer. Badges are assigned to:

- Anyone likely to receive more than 10% (500 mRem/5 mSv) of the annual limit.
- "Declared pregnant " individuals. Must declare in writing

Radiation Badges

The radiation badges are worn and exchanged based on the area or number of materials you use while working. Whole body badges worn in an unshielded position where the highest dose is expected.

Ring dosimeter should be worn facing RAM or radiation source

A report is generated at the end of each monitoring period and reviewed by the RSO.

Do not take home and return on time

Contact RSO immediately if lost

To learn more about personal radiation monitoring, you will need to contact your Radiation Safety Officer

Luxel Dosimer

Ring Dosimeter

Radiation Dosimetry Reports

Each person deemed a “Radiation Worker” has been assigned a whole-body badge. The badge tracks the amount of radiation received by the person wearing the badge.

An accredited company processes the badges and provides a monthly or quarterly report on radiation received for the wear period. Typical Landauer report shown below

PARTICIPANT NUMBER	NAME (ID NUMBER / BIRTH DATE / SEX)	DOSIMETER	USE	RADIATION QUALITY	DOSE EQUIVALENT (MREM) FOR PERIODS SHOWN BELOW			QUARTERLY ACCUMULATED DOSE EQUIVALENT (MREM)			YEAR TO DATE DOSE EQUIVALENT (MREM)			LIFETIME DOSE EQUIVALENT (MREM)			RECORDS FOR YEAR	INCEPTION DATE (MM/YY)
					DEEP DDE	EYE LDE	SHALLOW SDE	DEEP DDE	EYE LDE	SHALLOW SDE	DEEP DDE	EYE LDE	SHALLOW SDE	DEEP DDE	EYE LDE	SHALLOW SDE		
FOR MONITORING PERIOD:					03/01/07 - 03/31/07			QTR 1			2007							
00A27	CONTROL	Pa	CNTRL		M	M	M										3	01/05
	CONTROL	U	CNTRL				M											01/05
14656	KODIMER KORY	Pa	WHBODY	P	5	7	9	13	16	30	13	16	30	59	64	109	4	05/98
		U	RFINGR				50			180			180			910		05/98

Radiation Dosimetry Reports (cont.)

- Available for employee review.
- Can request at anytime during the year.
- All employees that are required to be monitored **must** receive an annual report if their annual exposure is greater then 100 mrem.
- *Employee* should maintain lifetime occupational dose record.

Internal Radiation Monitoring

Internal Monitoring – Bioassays

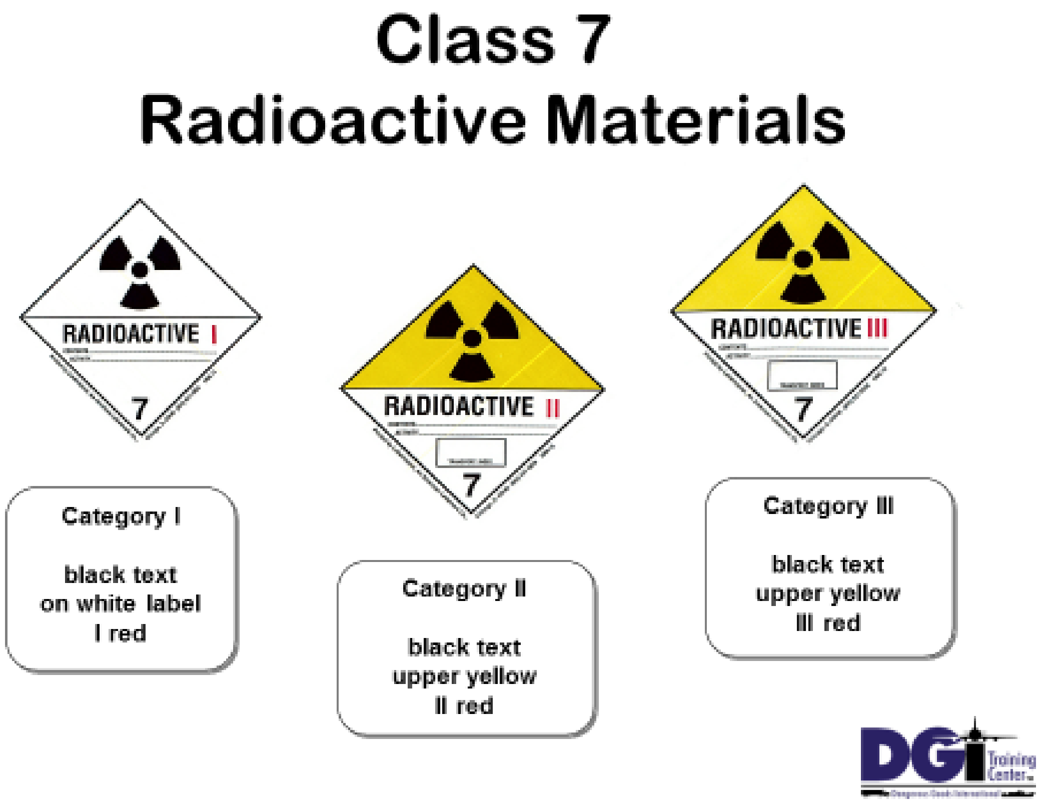
Bioassays are used to determine the internal dose received from the intake (ingestion, inhalation, injection) of radioactive materials.

- Thyroid Bioassay
  - A baseline (prior to use of radio-iodine) thyroid measurements will be taken.
  - Contact Radiation Safety Officer if you have any questions or concerns

- Special Bioassay-I131
  - Individuals that may have an intake of a radionuclide because of a spill incident or other occurrence will need to submit a bioassay.

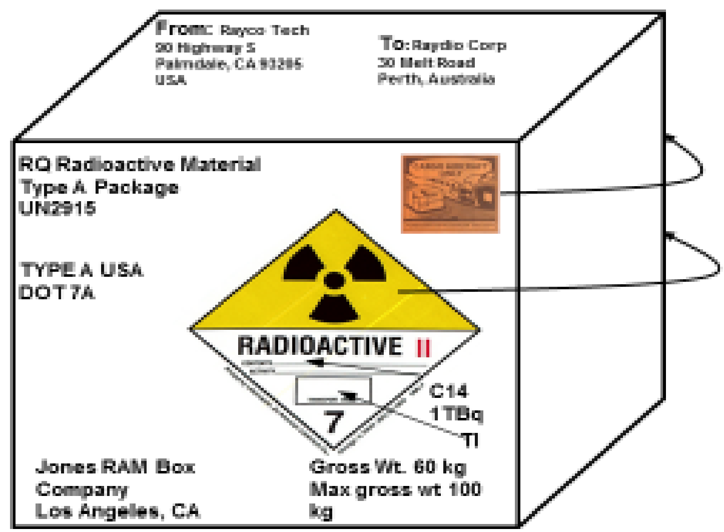
Contact your Radiation Safety Officer immediately if you have questions about internal monitoring

Radioactive Packages



Radioactive Packages (Cont.)

Marking and Labeling



Radioactive Packages (Cont.)

- Only authorized personnel should order Radioactive material. Typically, person under the supervision of AU or RSO can order isotopes e.g. Nuclear Medicine/PET technologist.
- Shipping of Radioactive Material must follow Department of Transportation regulations – not covered in this training. Contact Cardinal Health if you wish to receive DOT training.
- Follow your internal procedure for RAM package check in.
- Contact RSO immediately for any unusual circumstances.

Security of RAM

- Radioactive material must either be:
  - Locked
  - Under constant surveillance
  - Only authorized personnel should have access to hot lab and other restricted areas
  - If you are a mobile Nuclear Medicine/PET service provider, please follow your RAM license conditions.
- This includes:
  - Sealed sources
  - Marker / pointer sources
  - Radioactive waste (including in scan room)
  - Shipping containers (e.g. nylon cases, ammo boxes) with residual radioactive material (e.g. used syringes)
  - Flood sources/PET sources

Radiation Survey Meters

What is a radiation survey meter?

- A survey meter is a portable handheld, electronic instrument used to detect radiation. It must be calibrated annually.
- Portable survey instruments can be very useful in aiding workers in locating radioactive contamination.
- The type of detector (or probe) must be chosen according to the kind of radioactive material that is being used. Ludlum 14C couple with 44-9 pan cake probe is widely used in Nuclear Medicine/PET

Radiation Survey Meters (cont.)

GM Probes

- GM probes can detect beta and gamma emitters. It is one of the common survey meter used in Nuclear Medicine/PET.
- They are a good choice for locating gamma/beta emitting nuclides such as:
    - Tc-99m
    - I-131
    - Lu-177
    - PET Isotopes

- GM probes can measure in mR/hr and counts per minute (cpm)

Radiation Survey Meters (cont.)

Scintillation Probes

- Scintillation Probes commonly known as NaI probe are best for low gamma radiation
- Common low gamma emitters include:
  - I-125
  - Tc-99m

- Sensitive compared to GM probe
- Measures radiation in units of typically in microR/hr
- Ideal for waste disposal survey

Performing Radiation Surveys

__Radiation Survey__

- Always check the following prior to starting any survey:
    - Battery Check-must pass (batteries are not dead and/or corroded)
    - Function Check (no physical damage to the probes, etc)
    - Response Check (make sure the probe is responding with a known source and within % listed on calibration certificate)
    - Calibration is current
- Turn scale selector to the lowest setting.

Performing Radiation Surveys (cont.)

<u>Using Survey Meter</u>

- Performing Survey
    - Move the probe in a to side-to-side sweeping motion 1/8” to 1/4” above surface.
    - Determine whether the survey measurements should be in cpm or mR/hr.
        - Use cpm - for contamination measurements to determine how much activity is present.
        - Use mR/hr - for exposure rate determine absorbed dose in tissue.
        - Daily surveys are reported in mR/hr
    - Survey all areas where RAM is used and areas that are frequently touched by hands. Check your RAM license condition or contact your RSO regarding survey action limit.

Radiation Detection Equipment

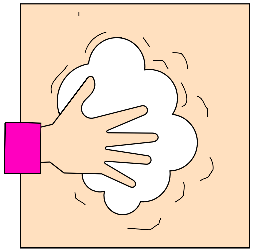
Well Counter

- Detects contamination
- Employs scintillation detector.
- Counts removable contamination on a wipe test (DOT package and daily or weekly wipe test)
- Needs Annual Calibration

Radioactive Spills

Contact Radiation Safety Officer immediately

In the event of a spill, it is important to contain the material and minimize exposure to oneself and others in the area. Follow these steps in case of a spill:



1. Stop the spill. Prevent any more material from escaping the area or container.
2. Warn Others. Inform others in the area of what and where the spill is located.
3. Isolate the Area. Restrict access to the spill area to only necessary personnel.
4. Minimize Exposure.
5. Secure or redirect ventilation (if applicable) in the event that the RAM is volatile.

If familiar with the material

- Decontaminate the area. Always move from the outside of the spill inward; from least contaminated areas to most contaminated areas.
- Survey the area to check if RAM has been removed. If not, continue to decontaminate the area.
- Dispose of the material used to clean up the spill as radioactive waste.
- If after several attempts, the contamination can not be removed, the area will need to be secured and decayed down to background levels

Personal Decontamination

If radioactive materials come in contact with you or your clothing, utilize the steps below:

- Remove outer wear (lab coat, gloves). 80% of contamination is contained in outer clothing.
- Rinse area with warm water. Lather with liquid detergent. Do not scrub or be abrasive to your skin.
- Contact Radiation safety Officer

Radioactive Waste

Radioactive waste should be disposed of in a way to prevent hazards to the health of personnel, value of property, and the community. Radioactive waste should be separated based on the half-life of the radioisotope and containers.

-Please follow your inhouse waste disposal procedure, if needed contact Radiation Safety Officer.

Radiation Safety Questions & Issues

Should you have any questions regarding radiation safety, either general or specific to your facility, please contact your management or Radiation Safety Officer.