Week 6: (1) Operational Health Physics (2) Nuclear Safety Culture

SAND2010-8174P

Unit 1: Operational Health Physics

Main Teaching Points/Lessons

1. Radiological Fundamentals
2. Biological Effects of Ionizing Radiation
3. Dose Equivalent Limits
4. As Low As Reasonably Achievable
5. Personnel Monitoring
6. Radiological Work Control
7. Radiological Events
8. High Radiation Safety
9. Contamination Control

Operational Health Physics

- Key Terms – Ionizing Radiation, Radioactivity, Contamination
- Key Concepts – ALARA, Work Control
- Desired Student Outcomes:
  1. Understand the fundamentals of radiation, radioactive material, and radioactive contamination
  2. Identify natural and manmade sources of radiation and the biological risks associated with radiation dose
  3. Describe radiation dose limits
  4. Describe exposure control concepts
  5. Discuss personnel monitoring programs
  6. Describe radiological work control methods and processes
  7. Identify the appropriate responses to radiological events
  8. Identify the requirements for entry into High Radiation Areas
  9. Understand contamination control methods

Operational Health Physics

Primary Resources

1. DOE-HDBK-1130-98, CN 1, February 2005, Radiological Worker Training (Recommended)
2. Basic Radiation Protection Technology, 5th Edition, Daniel Gollnick (Required)

- Can this topic be taught in a single lecture? No
- If no, how many lectures will it take? 12 hours for lecture series with an additional 6 hours for practical exercises
- Can these “sub”-lectures consist of the main teaching points? Yes
- Other comments/concerns: Will need protective clothing, personnel monitoring instruments and other equipment to facilitate practical exercises

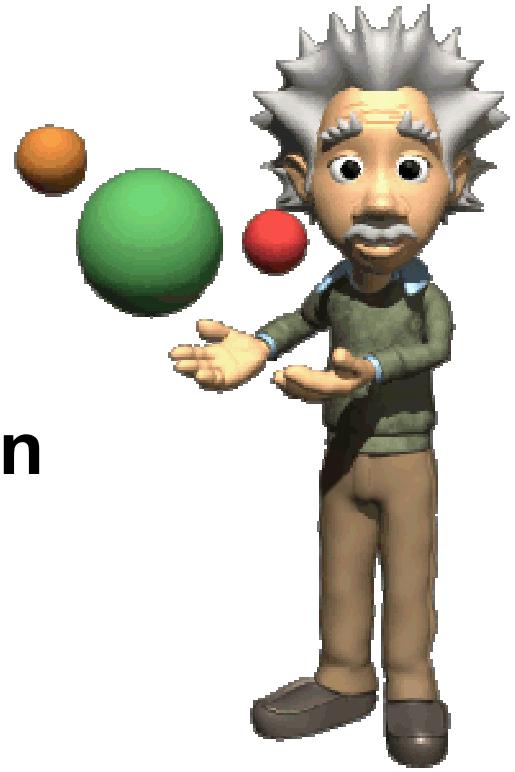
Lesson 1
Radiological Fundamentals

Radiation Review

Definitions

Types of Ionizing Radiation

Units of Measure



Lesson 1
Enabling Objectives

Understand the fundamentals of radiation, radioactive material, and radioactive contamination.

1. DEFINE ionization, radiation, radioactive material, and radioactive contamination.
2. DISTINGUISH between ionizing radiation and non-ionizing radiation.
3. DEFINE radioactivity and radioactive half-life.
4. IDENTIFY the physical characteristics, range and shielding, biological hazards and specific sources for each of the four types of ionizing radiation.
5. IDENTIFY the units used to measure radiation, radioactivity, and contamination.

Atomic Structure Review

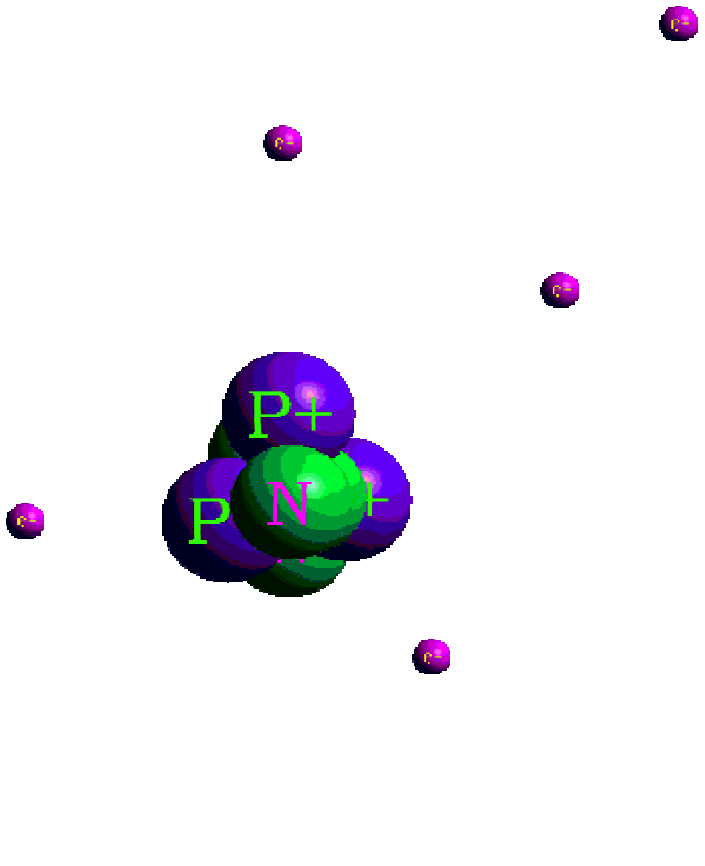
- Atomic Structure Particles
- Elements & Isotopes
- Stable vs. Unstable
- Standard Nomenclature
- Ions

Review of Atomic Structure

Protons (positive) P+

Neutrons (neutral) N

Electrons (negative) e-

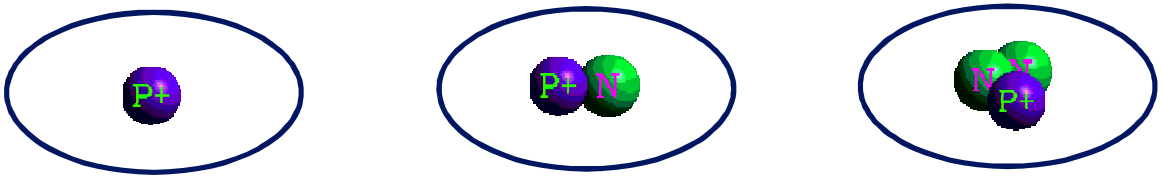


Elements & Isotopes

Elements: Identified by the number of Protons

hydrogen helium

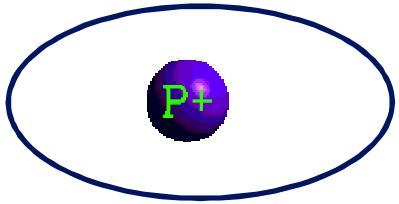
Isotopes: Atoms of the same element with different numbers of Neutrons



hydrogen (protium) hydrogen (deuterium) hydrogen (tritium)

Stable vs. Unstable Atoms

If there are too many or too few neutrons for a given number of protons, the nucleus will not be stable

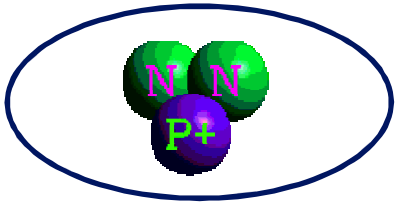


hydrogen

(protium)

STABLE

“Non-Radioactive”



hydrogen

(tritium)

UNSTABLE

“Radioactive”

Standard Nomenclature

of protons
and neutrons

$$ {}^{A}_{Z}X $$

Represents
element

# of protons

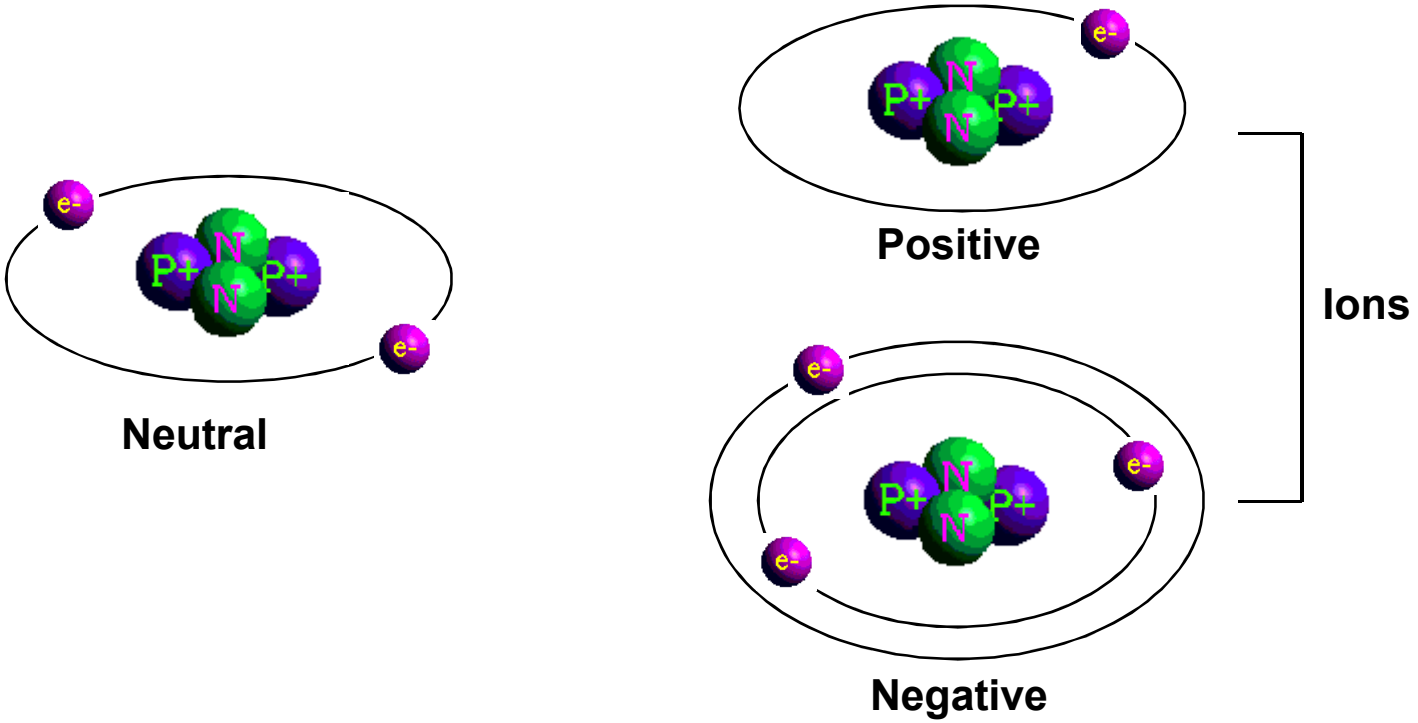
$$ {}^{60}_{27}Co $$

Definitions

- Ionization
- Radiation
- Ionizing vs. Non-Ionizing
- Radioactivity & Radioactive Decay
- Radioactive Half-Life
- Radioactive Material
- Radioactive Contamination

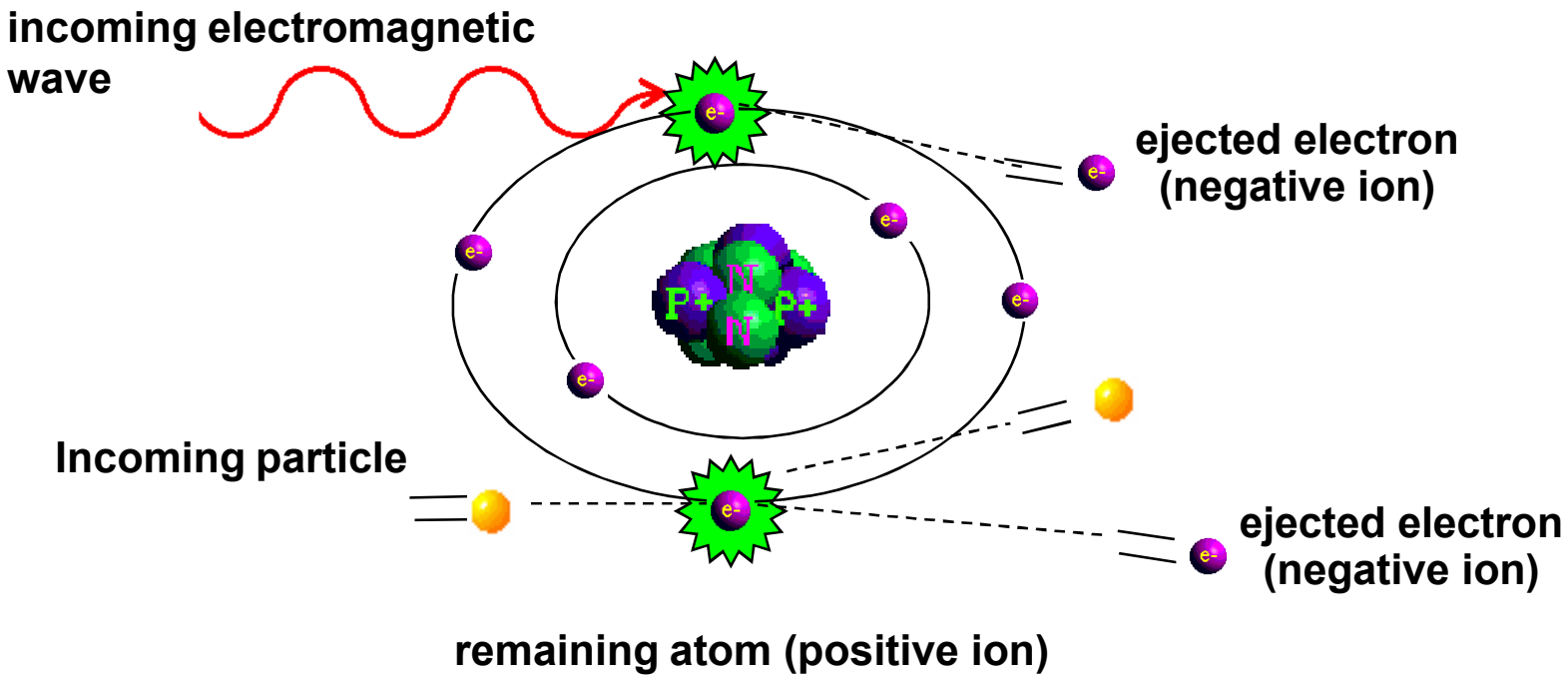
Ions

Ions are atoms with ***positive*** or ***negative*** charge



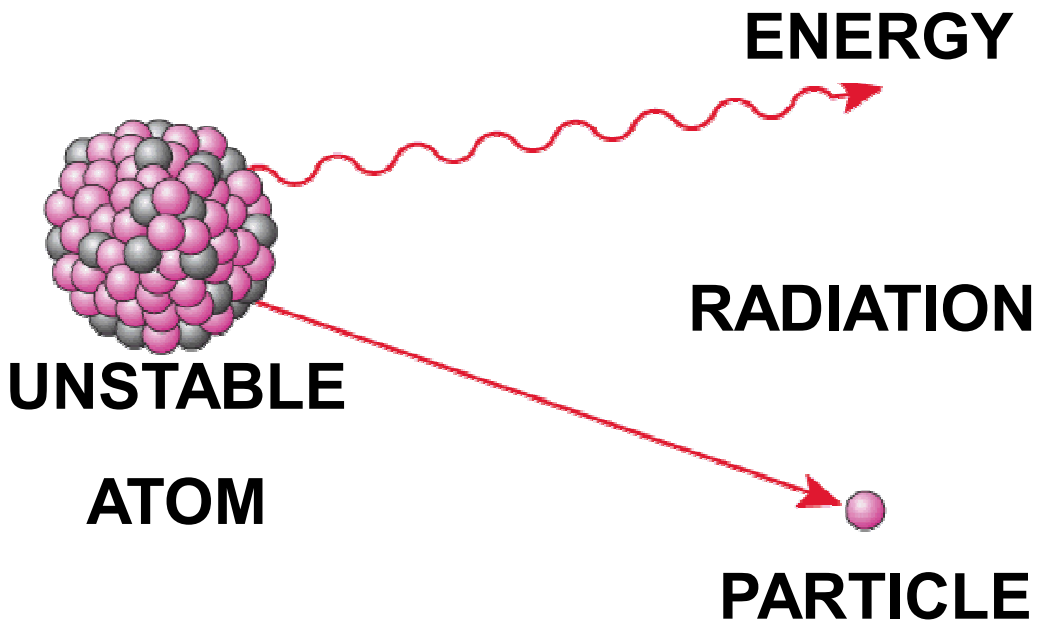
Ionization

The **process** of removing electrons from neutral atoms



Radiation

- **Energy** released from unstable atoms and some devices in the form of rays or particles
- Can be either ionizing or non-ionizing



Ionizing Radiation

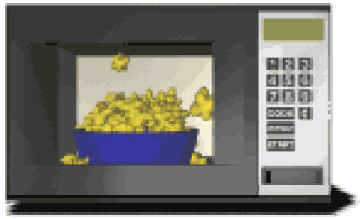
- Radiation that possesses enough energy to cause ionization in the atoms with which it interacts
- Released from unstable atoms and some devices in the form of rays or particles
  - alpha α
  - beta β
  - gamma/x-ray γ
  - neutron η

Non-Ionizing Radiation

- Radiation that does *not* have enough energy to ionize atoms with which it interacts
- Examples:
  - radio waves
  - infrared radiation
  - visible light
  - radar waves
  - microwaves

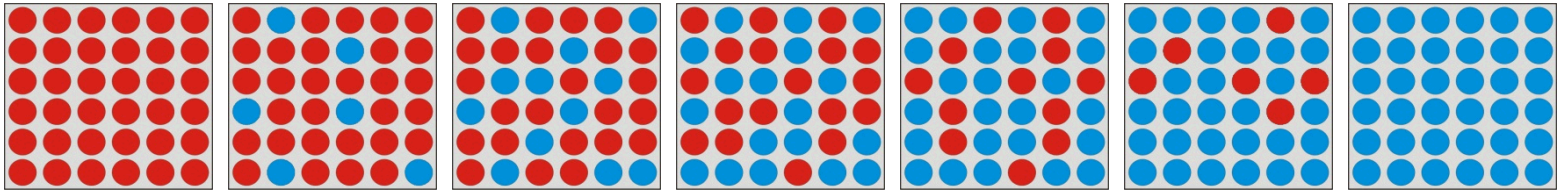


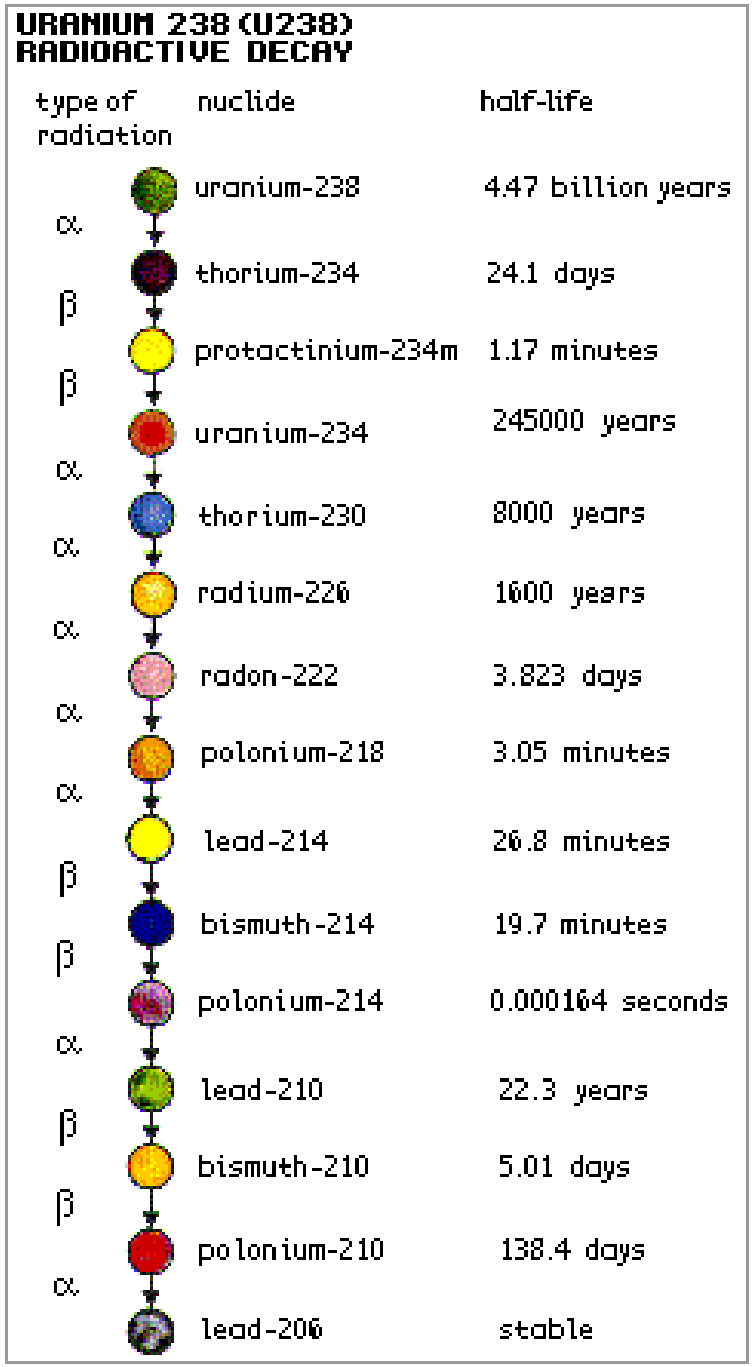




Radioactivity

The *process* of unstable (or radioactive) atoms becoming stable by emitting radiation. This event over time is called radioactive decay.

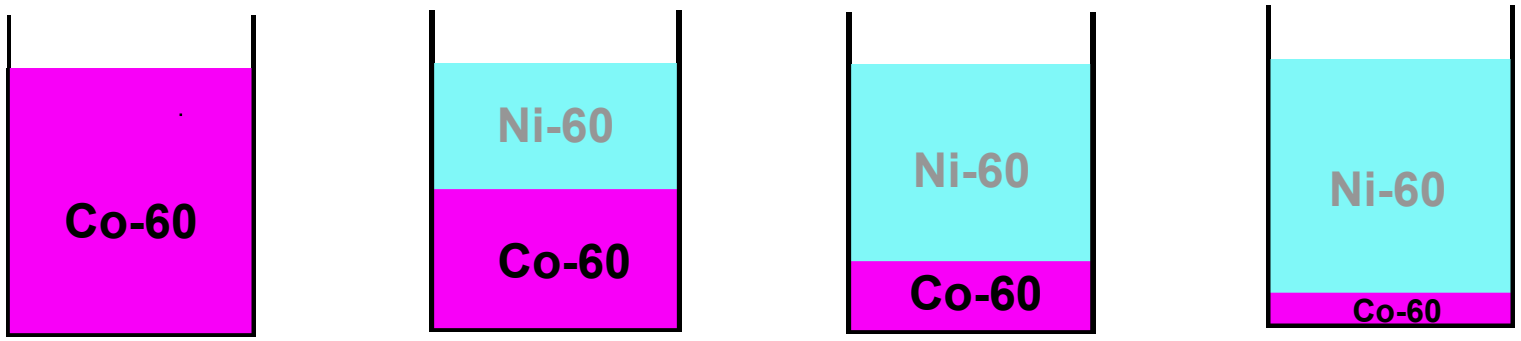



URANIUM 238 (U238)
RADIOACTIVE DECAY
type of radiation
nuclide
half-life
uranium-238
4.47 billion years
α
thorium-234
24.1 days
β
protactinium-234m
1.17 minutes
β
uranium-234
245000 years
α
thorium-230
8000 years
α
radium-226
1600 years
α
radon-222
3.823 days
α
polonium-218
3.05 minutes
α
lead-214
26.8 minutes
β
bismuth-214
19.7 minutes
β
polonium-214
0.000164 seconds
α
lead-210
22.3 years
β
bismuth-210
5.01 days
β
polonium-210
138.4 days
α
lead-206
stable

Radioactive Half-Life

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

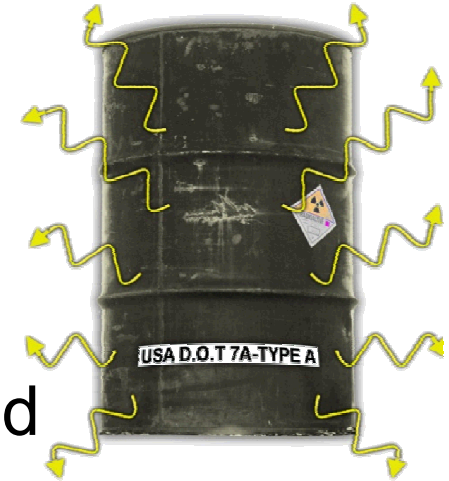
Example: Co-60 = 5 years

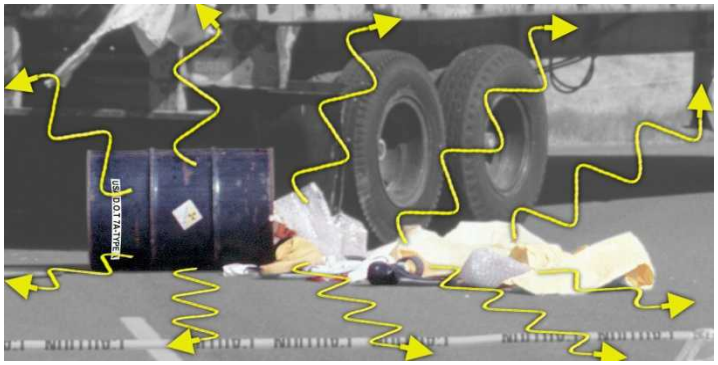


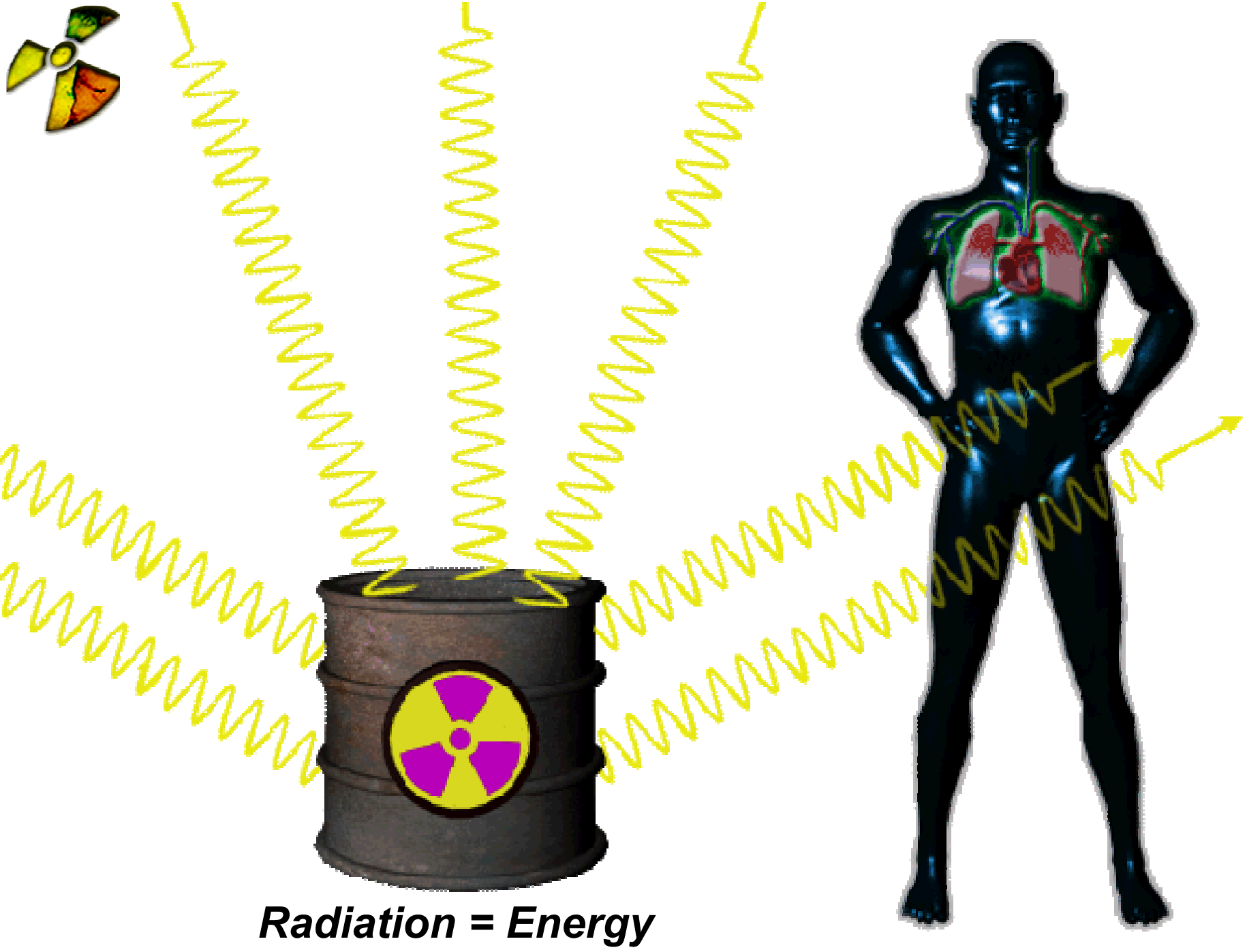
100 atoms today | **50 atoms after 5 yrs** | **25 atoms after 10 yrs** | **12 atoms after 15 yrs**

Radioactive Material and Radioactive Contamination

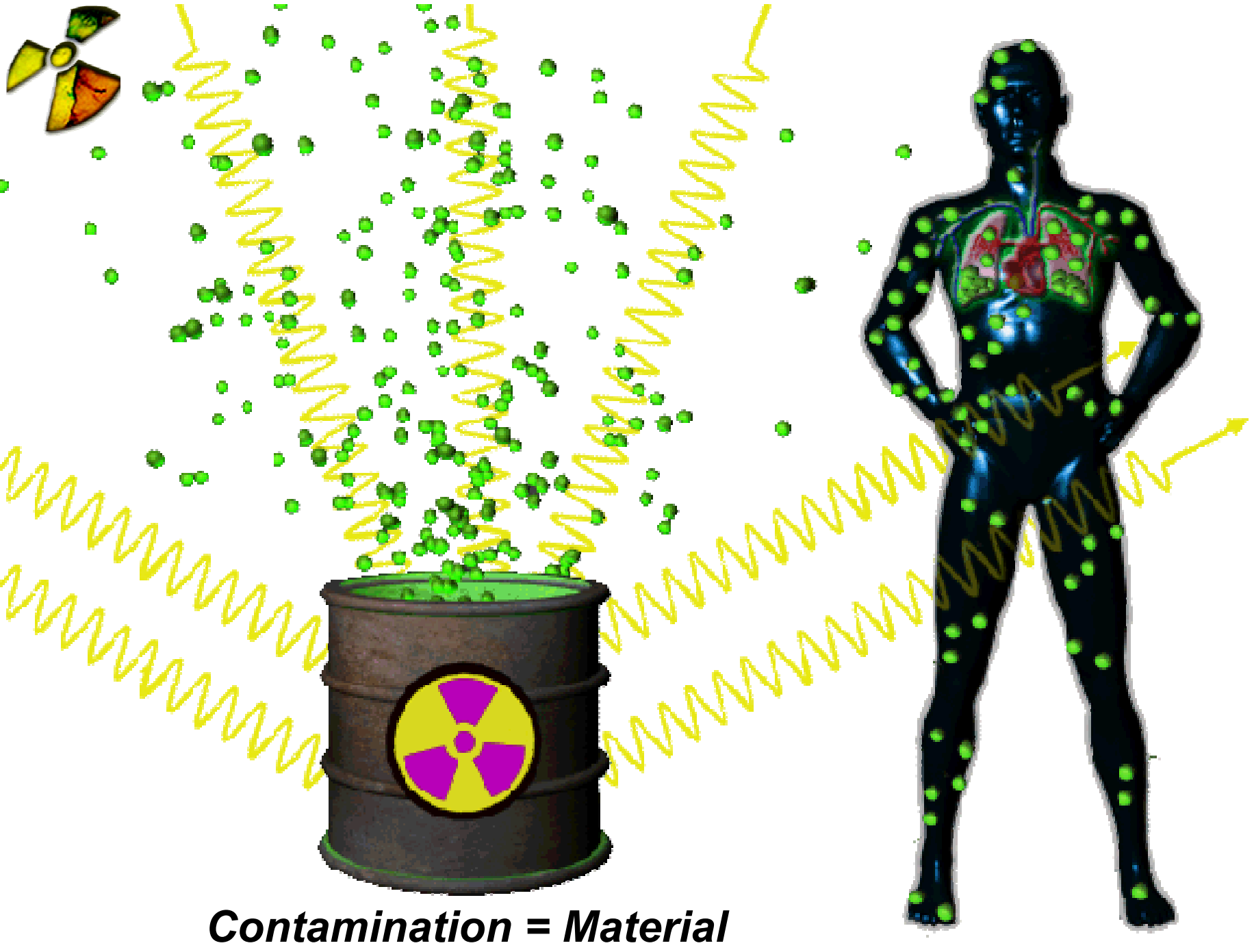
- Radiation is energy
- **Radioactive Material** - the physical material emitting the radiation
- **Radioactive Contamination** - radioactive material that is uncontained and in an unwanted place
- Exposure to radiation will *not* cause you to become contaminated



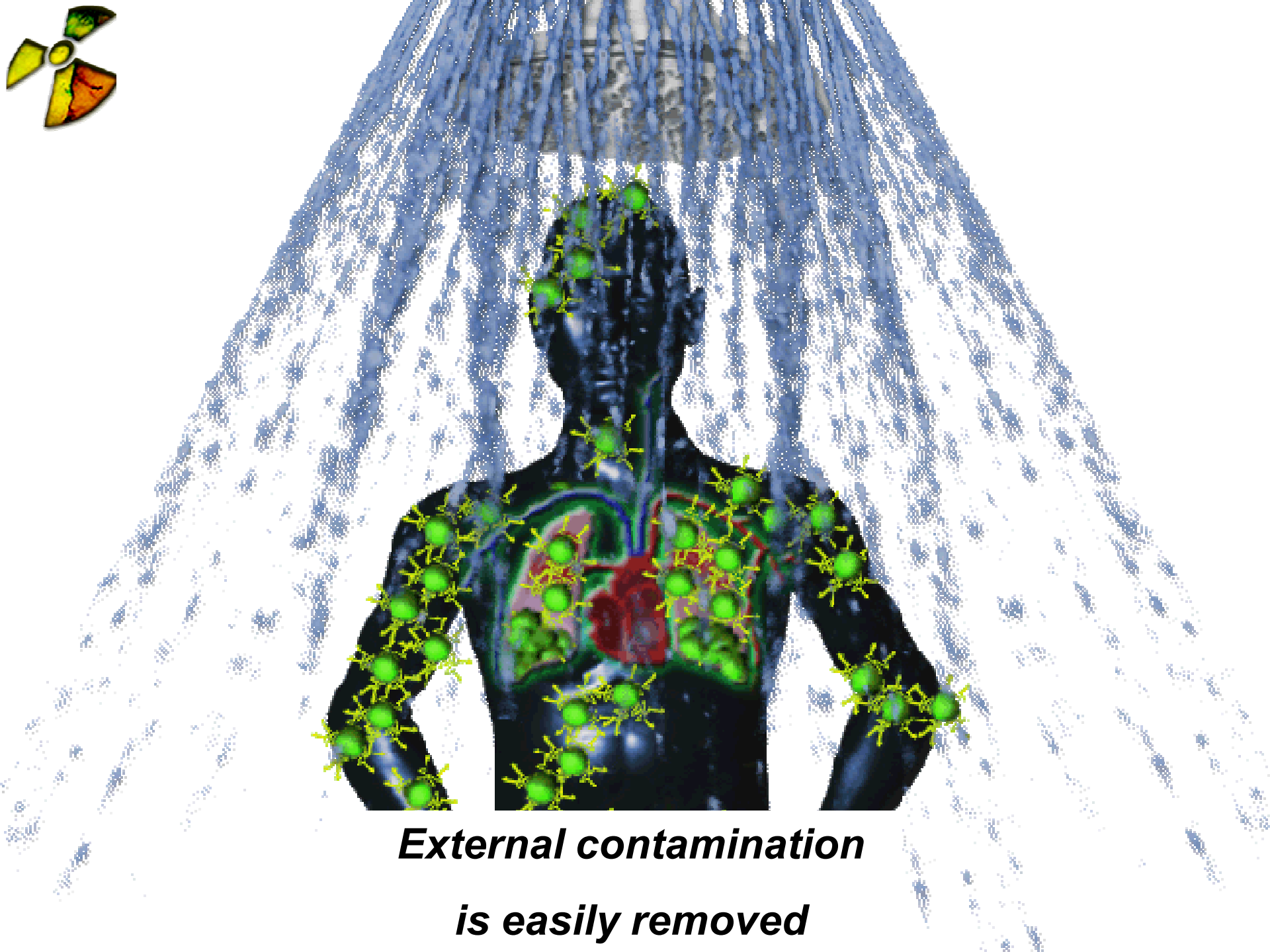




Radiation = Energy

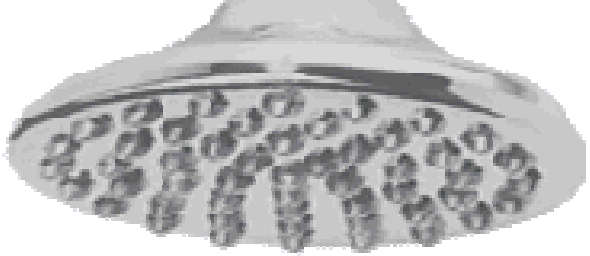


Contamination = Material



External contamination

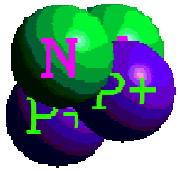
is easily removed



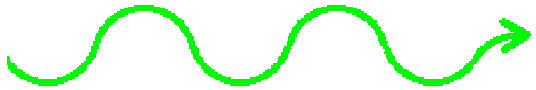
Internal contamination

is NOT easily removed

Types of Ionizing Radiation

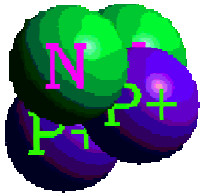
- Alpha (α) - particle 

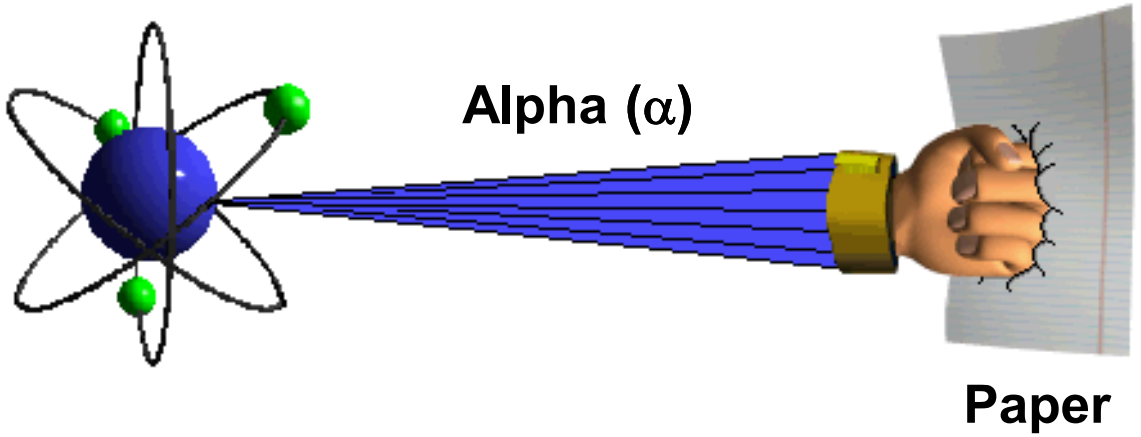
- Beta (β) - particle 

- Gamma (γ) / X - ray 
- Neutron (η) - particle 

Alpha Radiation (α)

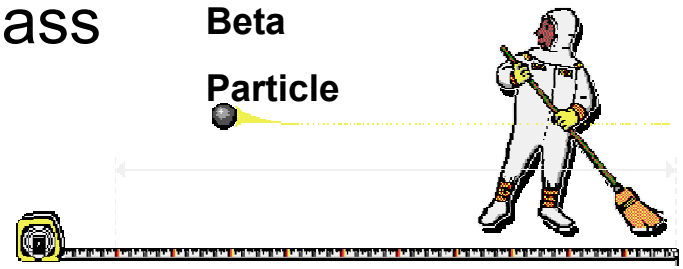
- Particle with a large mass
- Highly charged (+2 charge)
- Short range (2-5 cm in air)
- Significant internal hazard
- Easy to shield (paper, outer layer of skin)

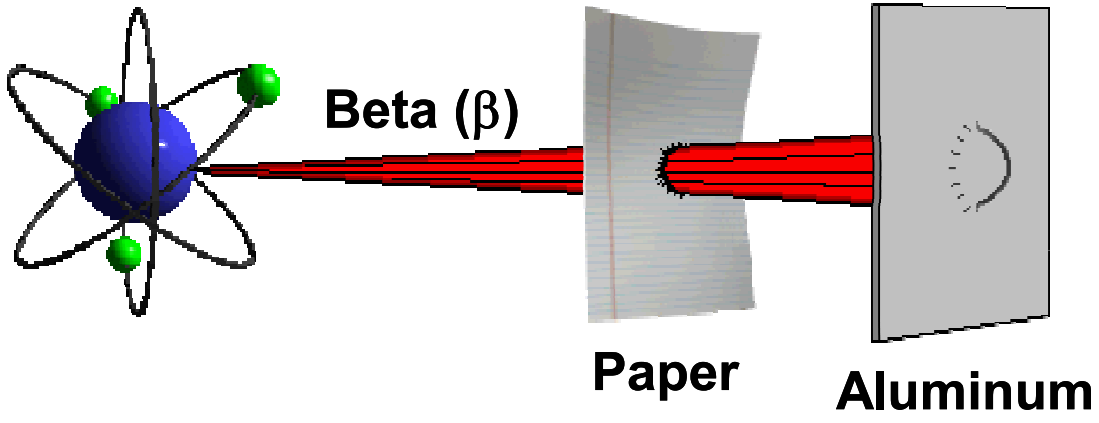


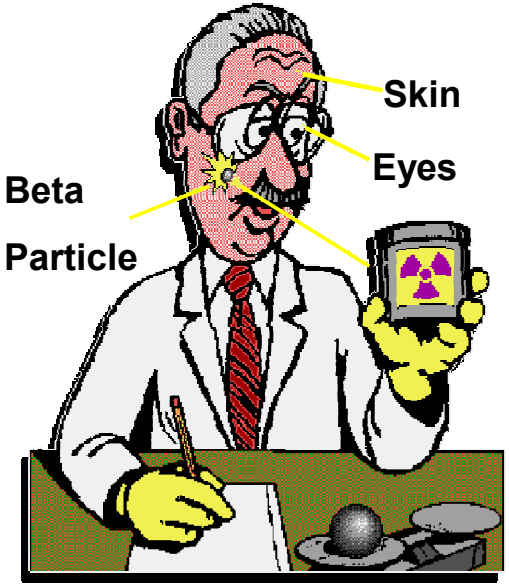


Beta Radiation (β)

- Particle with a relatively small mass
- Charged (-1 charge)
- Mid-range (3.5 meters/MeV)
- Potential internal and external hazard (skin, eyes)
- Shielding – plastic, glass, aluminum, wood

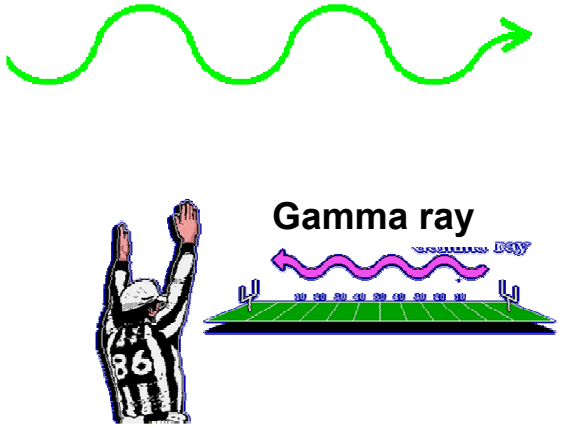


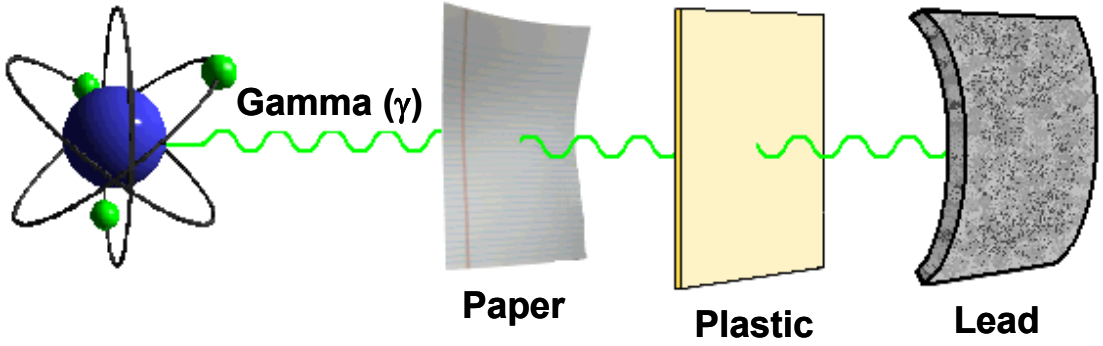


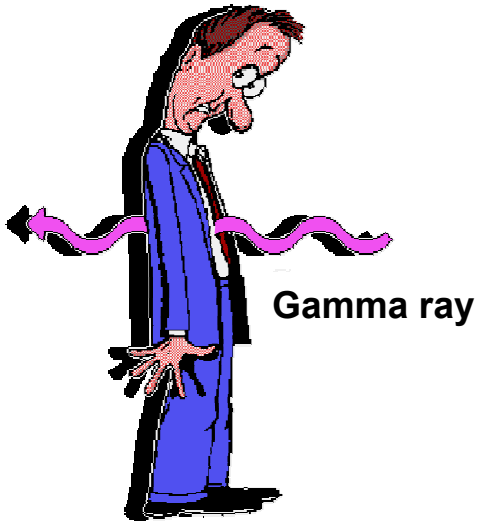


Gamma Rays (γ) and X-Rays

- Electromagnetic energy (ray)
- No mass, no charge
- Very long range
- Penetrating, whole body exposure hazard
- Difficult to shield – lead, steel, concrete



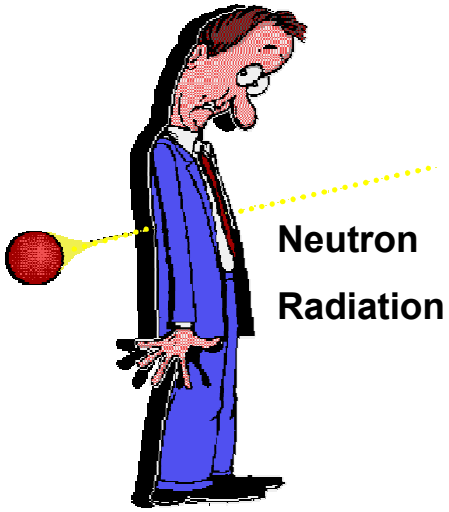


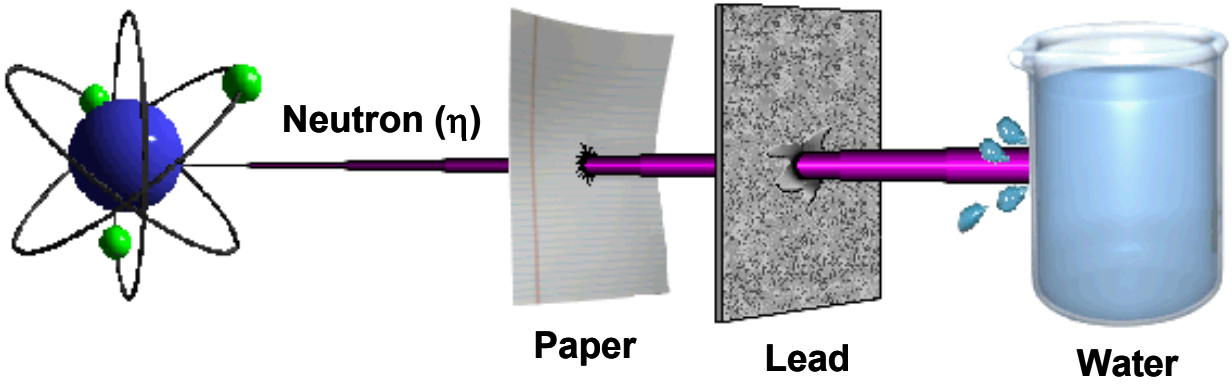


Neutron Radiation (η)

- Particle with no charge 

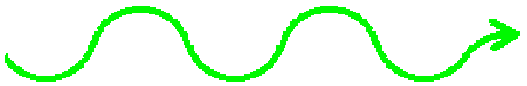
- Very long range
- Penetrating, whole body exposure hazard
- Shielding – water, polyethylene





Units of Measure

- **Radiation** ⟶ **Energy**



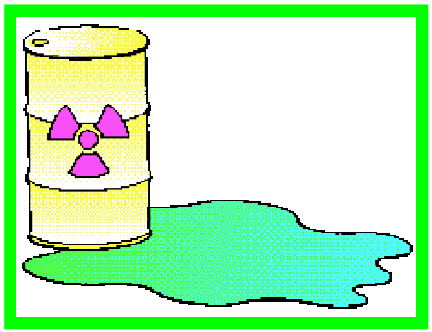
Roentgen, RAD, Gray, REM, Sievert

- **Radioactivity** ⟶ **Rate**

dpm, Becquerel, Curie

- **Contamination** ⟶ **Spread**

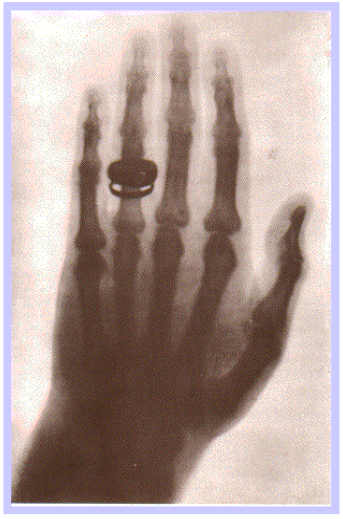
$$\frac{\text{Radioactivity}}{\text{Area or volume}}$$



Roentgen (R)

- Unit for measuring exposure
- Defined only for ionization in air
- Applies only to gamma and x-rays
- Not related to biological effects

Wilhelm Roentgen
1845 -1923
Discovered X-rays



Measuring Radiation Energy
- GRAY / RAD -

- SI Unit = GRAY (Gy) an absorbed dose of 1 joule/kilogram.
- Unit for measuring absorbed dose in any material
- Applies to all types of radiation
- Does not take into account the potential effect that different types of radiation have on the body
- Special Unit = Radiation Absorbed Dose (RAD)
- 1 Gy = 100 RAD

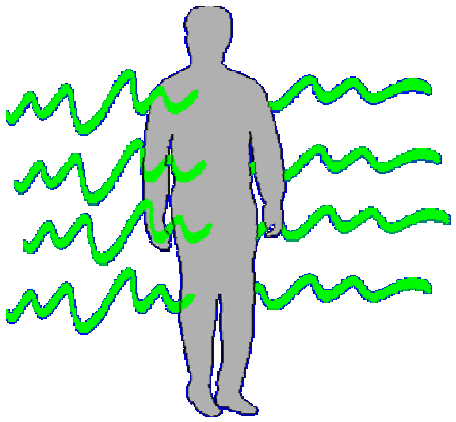
Measuring Radiation Energy - Sievert / Rem -

- SI Unit = Sievert (Sv) unit for measuring dose equivalence
- Pertains to the human body
- Takes into account the energy absorbed (dose) and the biological effect on the body due to the different types of radiation
- Special Unit = Roentgen Equivalent Man (Rem)
- 100 Rem = 1 Sv

Dose vs. Dose Rate

- Dose rate is the *rate* at which you receive the dose.
- Dose rate = dose divided by time (Gray/hr, mGray/hr, RAD/hr, mRAD/hr).
- Dose is the *amount* of radiation you receive.

Dose = Dose Rate X Time



200 mrem/hr

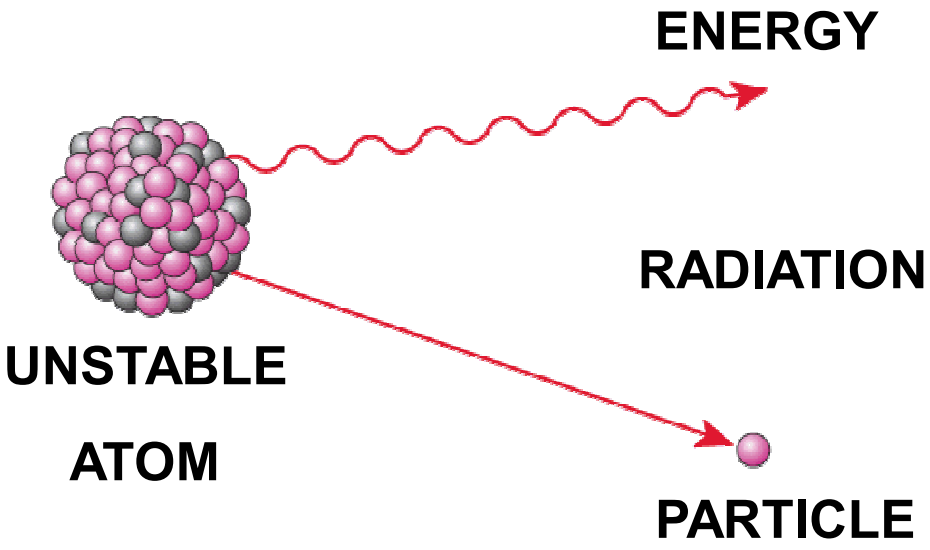
Question: How much dose would this individual receive in 15 minutes?

Answer: **50** mrem

Measuring Radioactivity

A measure of the number of disintegrations radioactive material undergoes in a certain period of time.

We measure the rate of decay which will lead us to the quantity of radioactive material present.



Radioactivity Units

Basic Unit

- Becquerel (Bq)
- 1 Bq = 1 disintegration per second (dps)
- dps = derived from instrument counts and counting efficiency

Larger unit

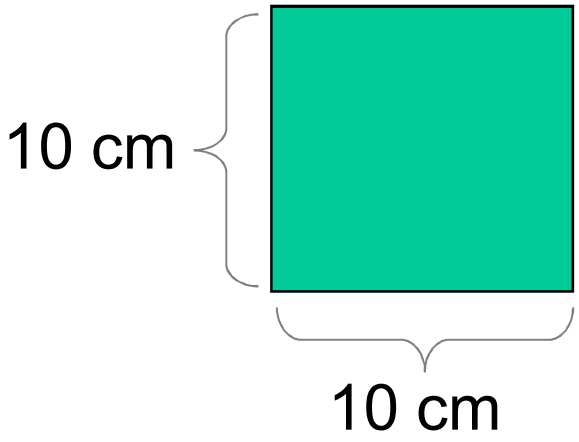
- Curie (Ci)
- 1 Ci = 2.22 x 10^{12} dpm
- 1 Ci = 3.7 x 10^{10} dps

Marie Curie
1867 - 1934
Discovered
radium & polonium

Contamination Units

How spread out is the radioactive material?

$$\frac{\text{Radioactivity}}{\text{Area or Volume}}$$



$$\frac{\text{dpm}}{100\ \text{cm}^2}$$

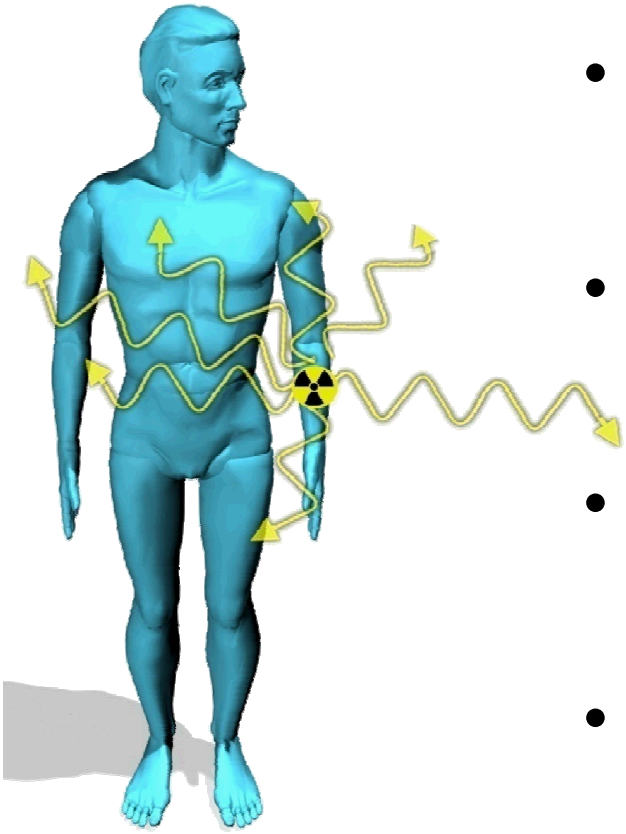
(dpm = disintegrations per minute)

Lesson 1 Quiz

+

Break

Lesson 2
Biological Effects



- Background Sources
- Radiation Effects
- Prenatal Exposure
- Risks in Perspective

Lesson 2
Enabling Objectives

Identify natural and manmade sources of radiation and the biological risks associated with radiation dose

1. IDENTIFY the major sources of natural background and manmade radiation.
2. IDENTIFY the average annual dose to the world population from natural background and manmade sources.
3. STATE the method by which radiation causes damage to cells.
4. IDENTIFY the possible effects of radiation on cells.

Lesson 2
Enabling Objectives (Cont.)

5. DEFINE the terms “acute dose” and “chronic dose.”
6. STATE examples of chronic radiation dose.
7. DEFINE the terms “somatic effect” and “heritable effect.”
8. STATE the potential effects associated with prenatal radiation dose.
9. COMPARE the biological risks from chronic radiation doses to health risks that workers are subjected to in industry and in daily life.

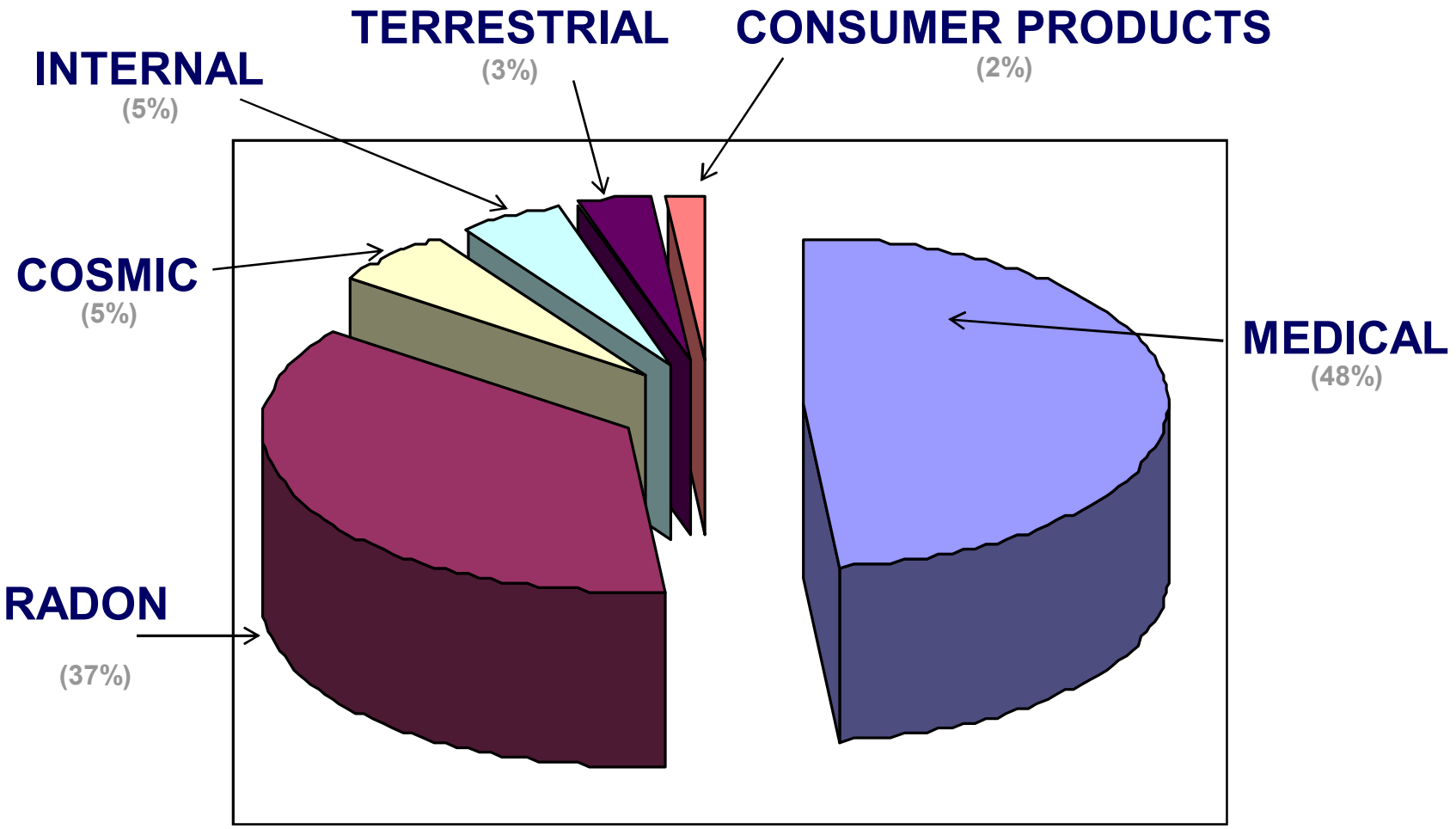
Background Radiation

Background = natural + manmade

We are constantly exposed to background radiation, from both natural and manmade sources

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

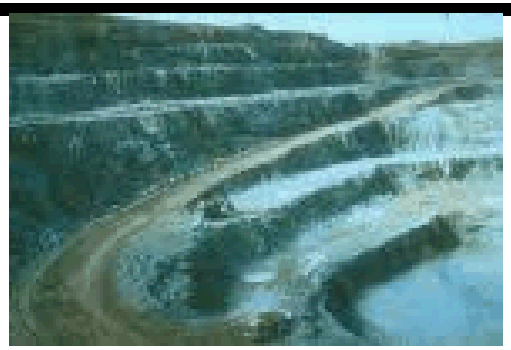
Background Sources of Ionizing Radiation



Reference: National Council on Radiation Protection & Measurements, *Ionizing Radiation Exposure of the Population of the United States*, March 3, 2009

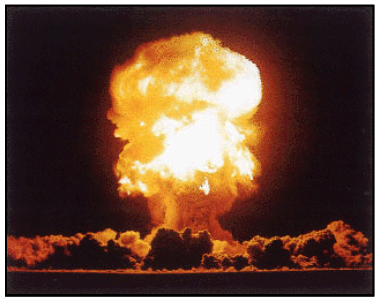
Natural Background Sources

SOURCE	AVG DOSE
COSMIC - sun & outer space	34 mrem/yr
TERRESTRIAL - Earth's crust	22 mrem/yr
INTERNAL - our own bodies	28 mrem/yr
RADON - Uranium in the Earth	227 mrem/yr



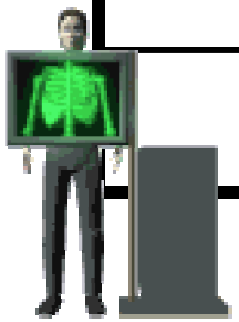
Man-Made Radiation Sources

SOURCE	AVG DOSE
Medical	300 mrem/yr
Consumer Products	10 mrem/yr
Industrial Uses	< 1 mrem/yr
Atmospheric Testing	< 0.5 mrem/yr

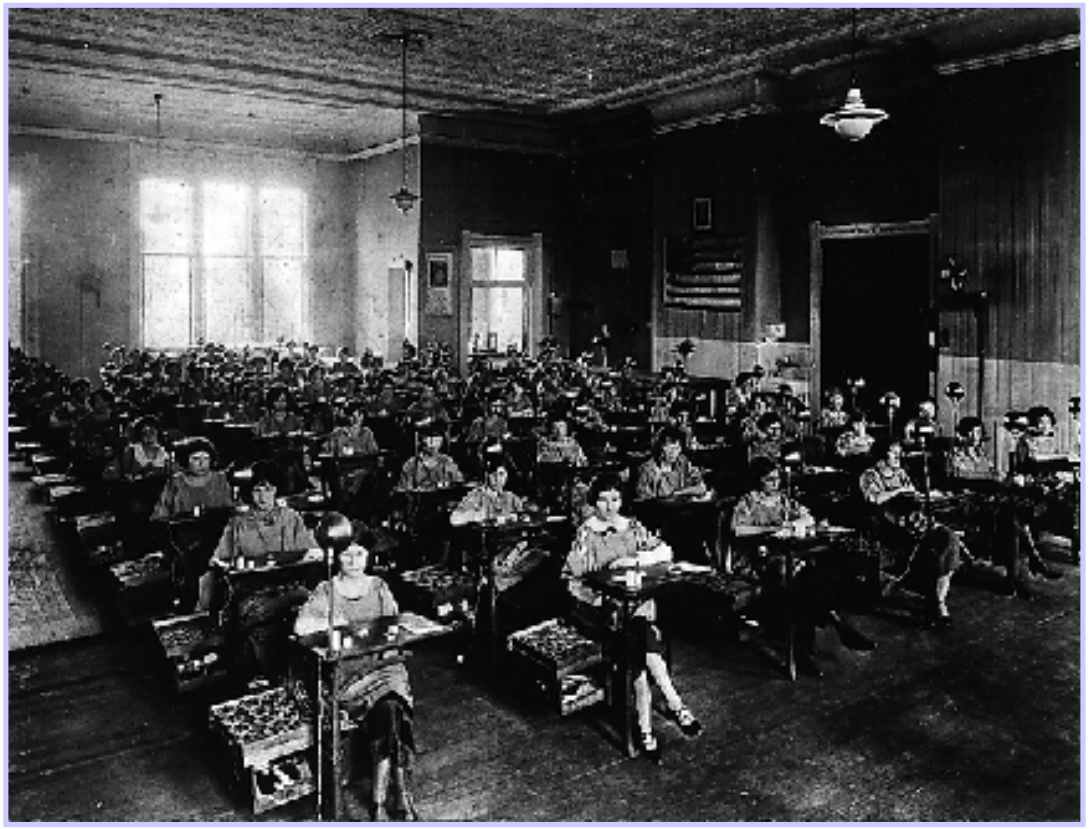


Radiation Doses
- Medical Procedures -

Radiation Therapy	600,000 mrem - tumor
CAT Scan	5,800 mrem - head 1,500 mrem - lower spine
Fluoroscope	5,000 mrem/min. - skin
Mammogram	400 mrem - breast 0.2 mrem (low-dose screen)
Dental X-Ray	55 - 65 mrem/shot - mouth
Chest X-Ray	20 - 50 mrem/shot - chest



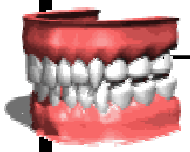
Radiation Doses
- Consumer Products -



Radium Dial Factory

Radiation Doses
- Consumer Products -

PRODUCT	AVG DOSE
Cigarettes (1.5 packs/day)	8,000 mrem/yr - lungs
Dental Porcelain	60 rem/yr - gums
Tinted Glasses	4 rem/yr - eyes
Building Materials	7 mrem/yr - whole-body
Radium Dial Watch	6 mrem/yr - whole-body
Smoke Detector	1 mrem/yr - whole-body



World Average

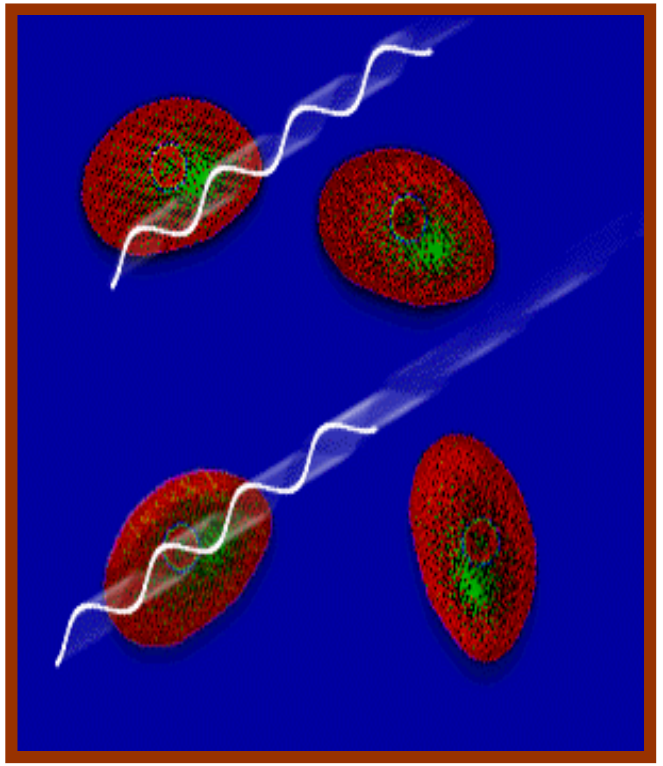
The average annual doses to the world population from all sources of radiation is estimated to be ***280 mrem/year*** (2.8 mSv/year). (IAEA Report)

Radiation Effects

- Cell Damage
- Cell Sensitivity
- Possible Effects on Cells
- Radiation Damage Factors
- Acute vs. Chronic
- Somatic vs. Heritable

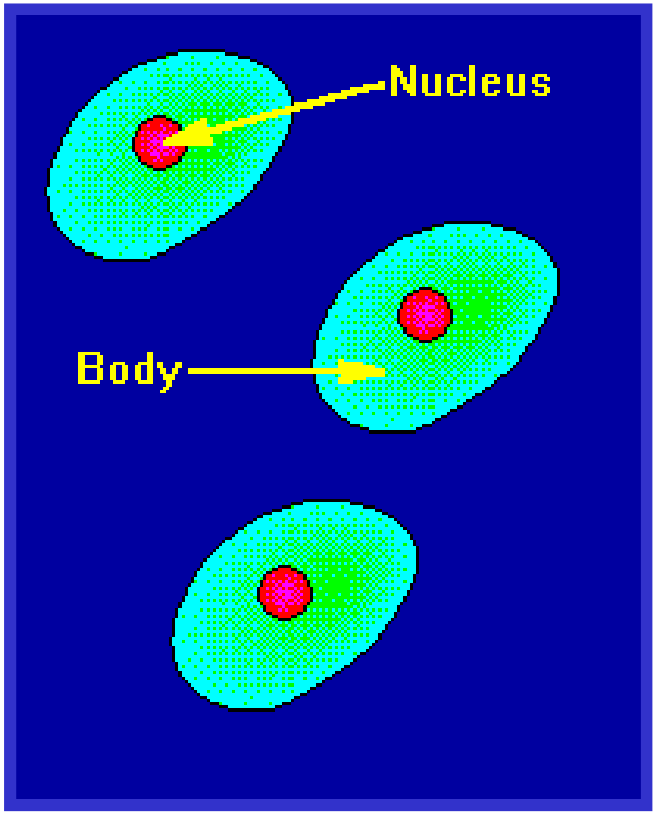
Cell Damage

The human body is made up of many organ systems. Each system is made up of tissues. Specialized cells make up tissues. Ionizing radiation can potentially affect the normal function of cells.



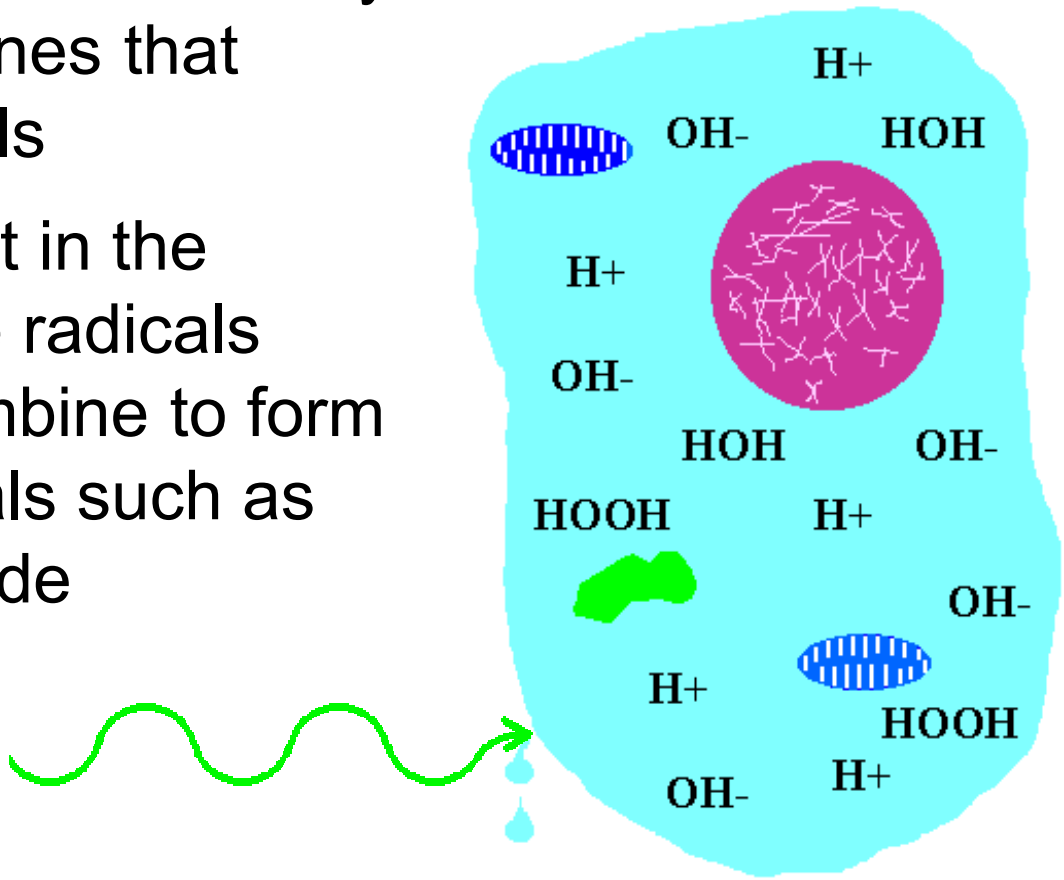
Cell Damage (Cont.)

The method by which radiation causes damage to human cells is by *ionization of atoms in the cells*. Any potential radiation damage begins with damage to atoms.



Cell Damage (Cont.)

- Ionizing radiation can directly rupture membranes that surround the cells
- Ionizations result in the formation of free radicals which can recombine to form harmful chemicals such as hydrogen peroxide



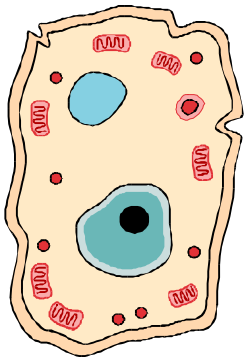
Cell Sensitivity

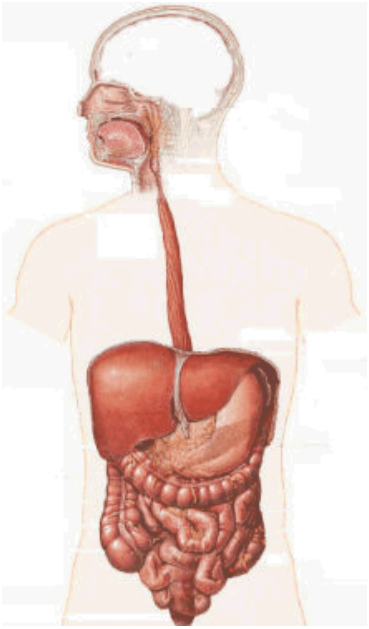
Some cells are more sensitive than others to environmental factors such as:

- Viruses
- Toxins
- Ionizing radiation

Highest Sensitivity

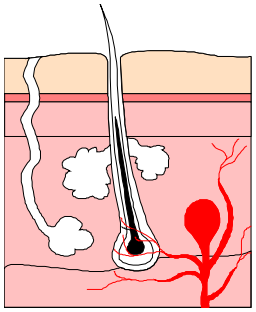
- Actively dividing cells
- Non-specialized cells





EXAMPLES:

- Blood forming cells
- Hair follicles
- Cells that form sperm
- Intestinal tract lining

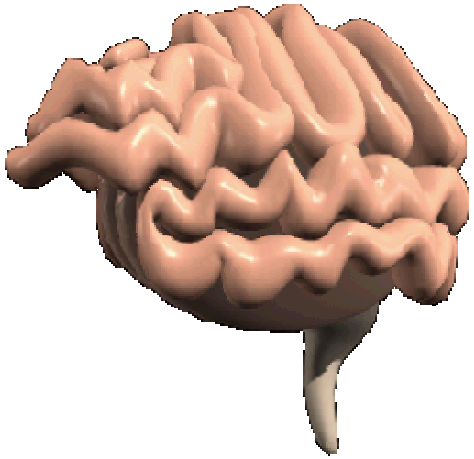


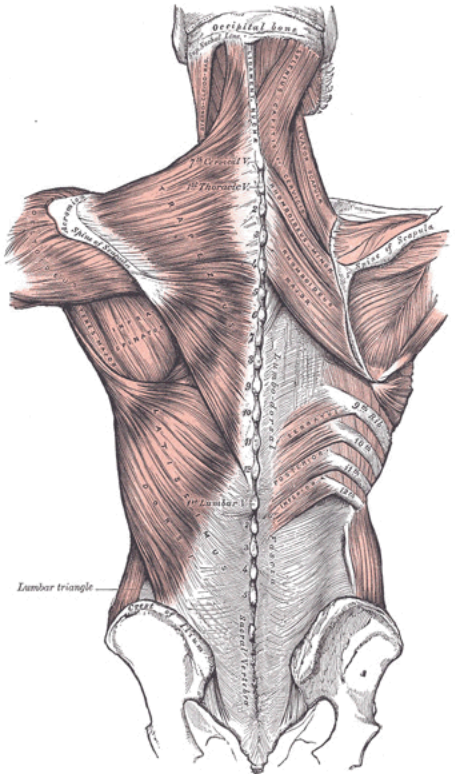
Lowest Sensitivity

- Less actively dividing cells
- More specialized cells

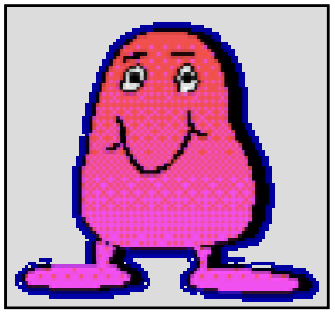
EXAMPLES:

- Brain cells
- Muscle cells

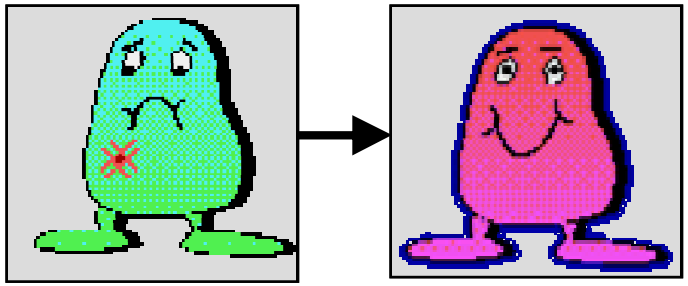




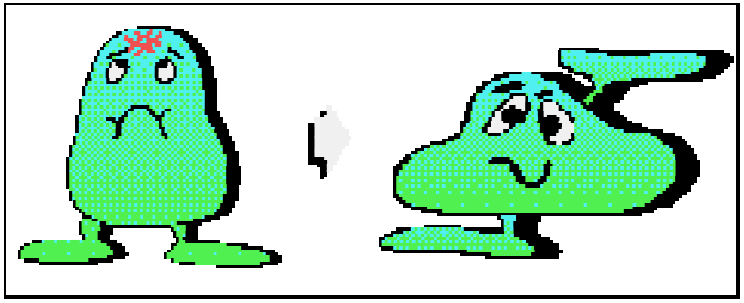
Possible Effects of Radiation on Cells



There is no damage



Cells repair the damage and operate normally



Cells are damaged and operate abnormally

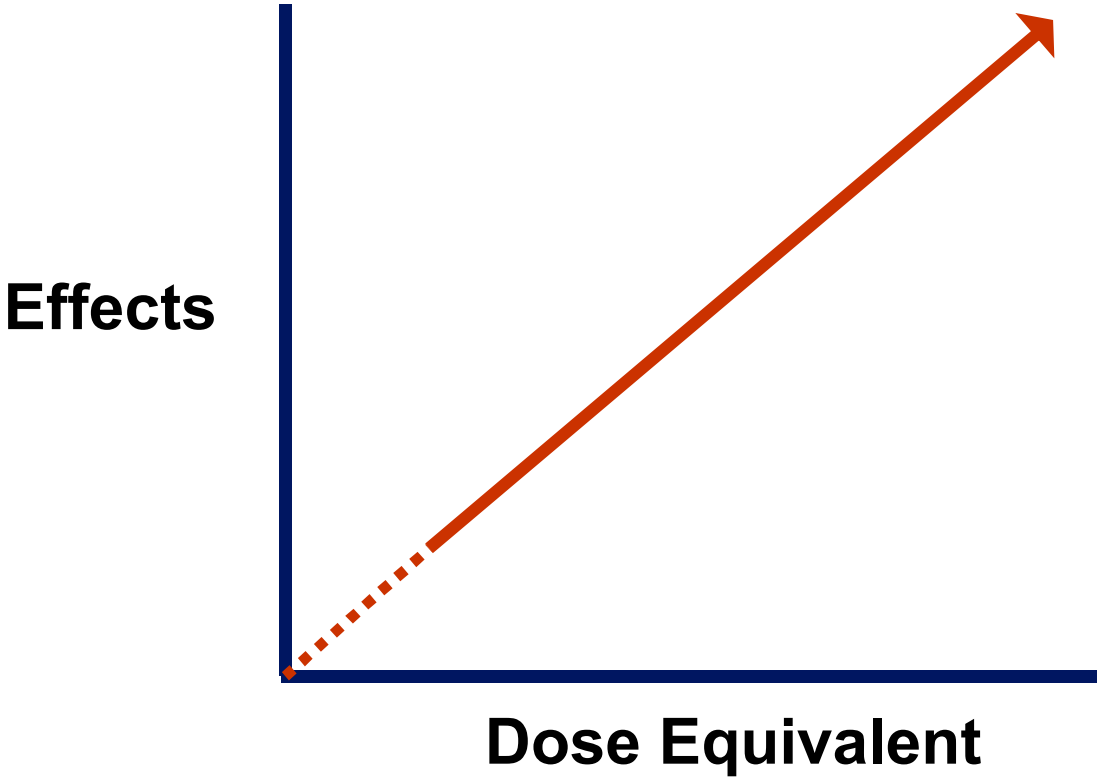
Cells die

Radiation Damage Factors

- Total Dose
- Dose Rate
- Type of Radiation
- Area of Body Exposed
- Individual Sensitivity

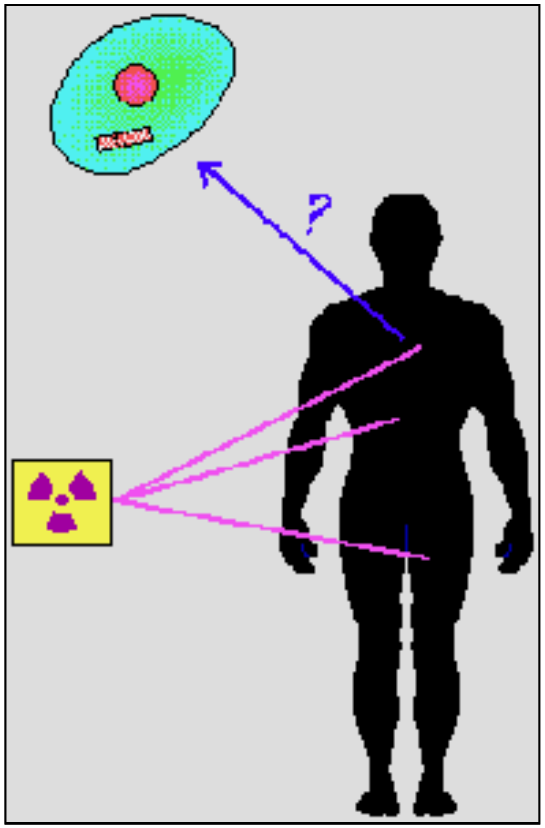
Total Dose

In general, the greater the dose, the greater the potential for biological effects.



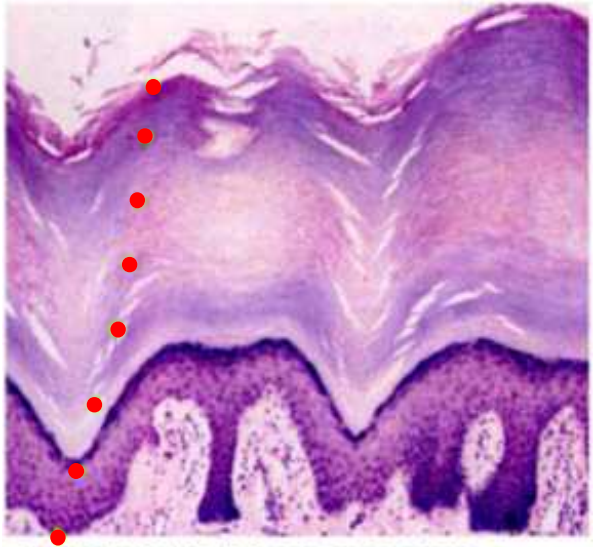
Dose Rate

The faster the dose is delivered, the less time the body has to repair itself.

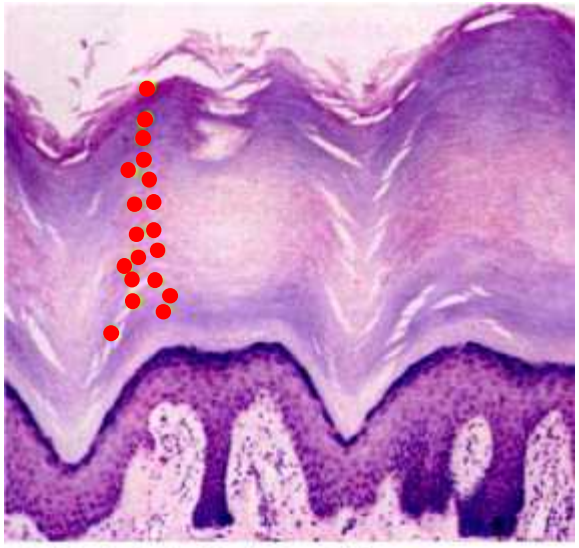


Type of Radiation

For example, internally deposited alpha emitters are more damaging than x-rays or gamma rays for the same energy deposited.



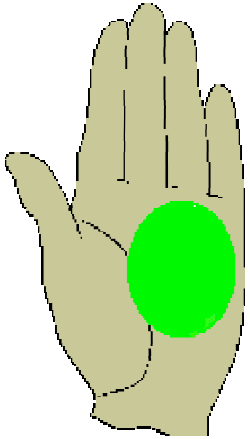
Specific ionization by X or gamma rays



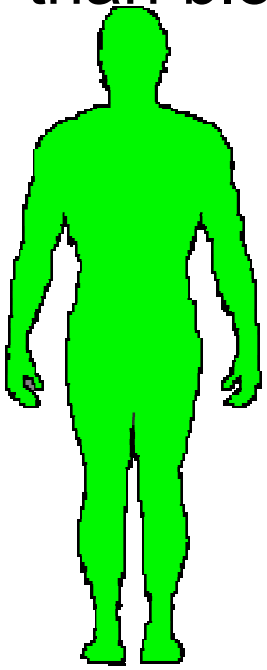
Specific ionization by alpha particles

Area of Body Exposed

- In general, 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.



vs.



Individual Sensitivity

- Age
  - The human body becomes less sensitive to ionizing radiation with increasing age; however, elderly people are more sensitive than middle-aged adults.

- Genetic make-up
  - Some individuals are more sensitive to environmental factors.

Acute vs. Chronic Dose

Potential biological effects depend on how much and how fast a radiation dose is received.

Radiation doses are grouped into:

- **Acute** - high dose of radiation received in a short period of time (seconds to days)
- **Chronic** - a small dose of radiation received over a long period of time (months to years)

Acute Dose

The body's cell repair mechanisms are not as effective for repairing damage caused by an acute dose.

- Damaged cells will be replaced by new cells and the body will repair itself, although this may take a number of months.
- In extreme cases the dose may be high enough that recovery would be unlikely.

Acute Exposure Effects

AVG DOSE	DAMAGE
2 - 5 rem (0.02 – 0.05 Sv)	Annual Limit
25 - 50 rem (0.25 – 0.50 Sv)	Slight Blood Changes
100 - 200 rem (1 – 2 Sv)	Radiation Sickness
200 - 500 rem (2 – 5 Sv)	Blood System Damaged
450 - 600 rem (4.5 - 6 Sv)	LD 50-60
> 500 rem (>5 Sv)	Gastrointestinal Damage
> 5000 rem (> 50 Sv)	Death Within 2-3 days

Effects of High-Level Acute Doses (Skin/Extremities)

Burns (Erythema)

Necrosis

Loss of fingers / limbs

Chronic Dose

A small dose of radiation received over a long period of time.

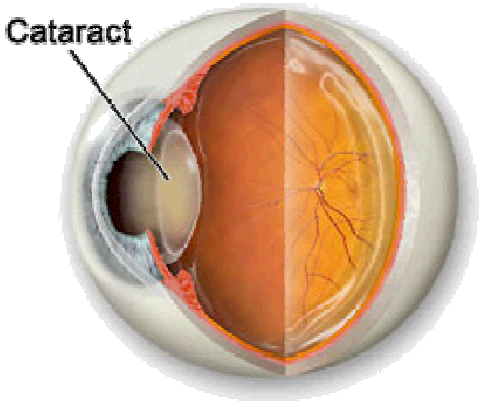
Typical examples are:

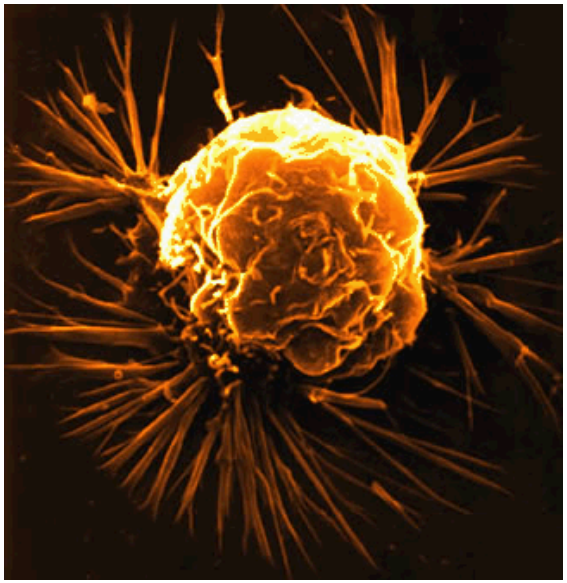
- The dose we receive from natural background
- The dose from occupational exposure

The human body is better equipped to tolerate chronic doses

Effects of Chronic Doses

- Increased risk of cataract formation - if over 4.5 Sieverts (450 rem)
- Increased risk of developing cancer





Somatic vs. Heritable

- Somatic effects appear in the exposed individual. Some examples:
  - Cells may become cancerous
  - Increased risk of cataract formation
  - Possible life shortening

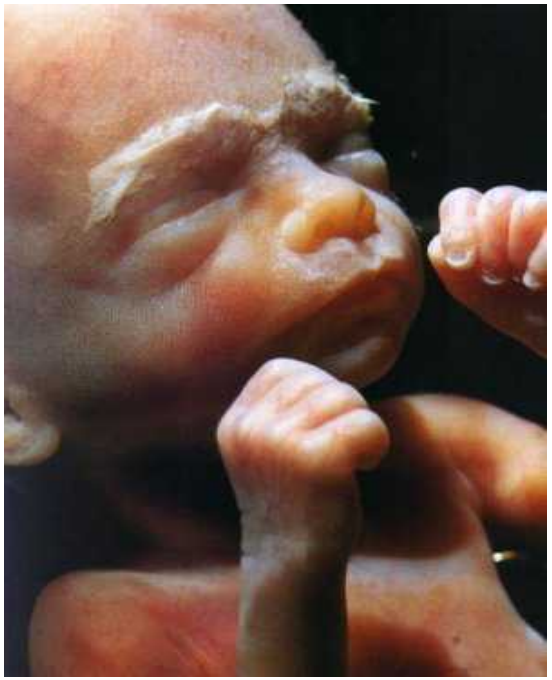
- Heritable (genetic) effects appear in future generations
  - Not yet observed in human populations

Prenatal Exposure

- Prenatal Sensitivity
- Potential Prenatal Effects

Prenatal Sensitivity

Embryo/fetus cells are rapidly dividing, which makes them sensitive to many environmental factors including ionizing radiation.



Potential Prenatal Effects

Although no effects were seen in Japanese children conceived after the atomic bomb, the following effects were seen in some children who were in the womb when exposed to radiation:

1. Slightly Smaller Head Size
2. Lower Average Birth Weight
3. Increased Incidence of Mental Retardation
4. Increased Risk of Childhood Cancer

Risks in Perspective

- Cancer Risk Info
- Comparison of Health Risks
- Occupational Risk Comparison

Cancer Risk

- Current rate of cancer death is about 20%.
- An individual who receives 250 millisieverts over a working life increases his/her risk of cancer by 1% to about 21%.
- The average annual dose to U.S. radiological workers is less than 1 millisievert.

Comparison of Health Risks

Health Risk	Days Lost
Unmarried Male	3500
Tobacco User	2250
Unmarried Female	1600
Overweight Individual	777
Alcohol Consumer	365
Motor Vehicle Driver	207
100 mrem/yr for 70 yrs	10

Comparison of Occupational Risk

Industry	Days Lost
Coal Miner	328
Farmer	277
Transportation Worker	164
Average	74
Manufacturer	43
Radiological Worker	40
Trades Employee	30

Lesson 2 Quiz

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Break

Lesson 3
Radiation Limits

- **Basis and Purposes for Dose Limits and Administrative Control Levels**
- **Dose Limits and Administrative Control Levels**

Lesson 3
Enabling Objectives

Describe radiation dose limits

1. STATE the purpose of administrative control levels.
2. IDENTIFY typical radiation dose limits.
3. DESCRIBE radiation exposure considerations for pregnant workers.

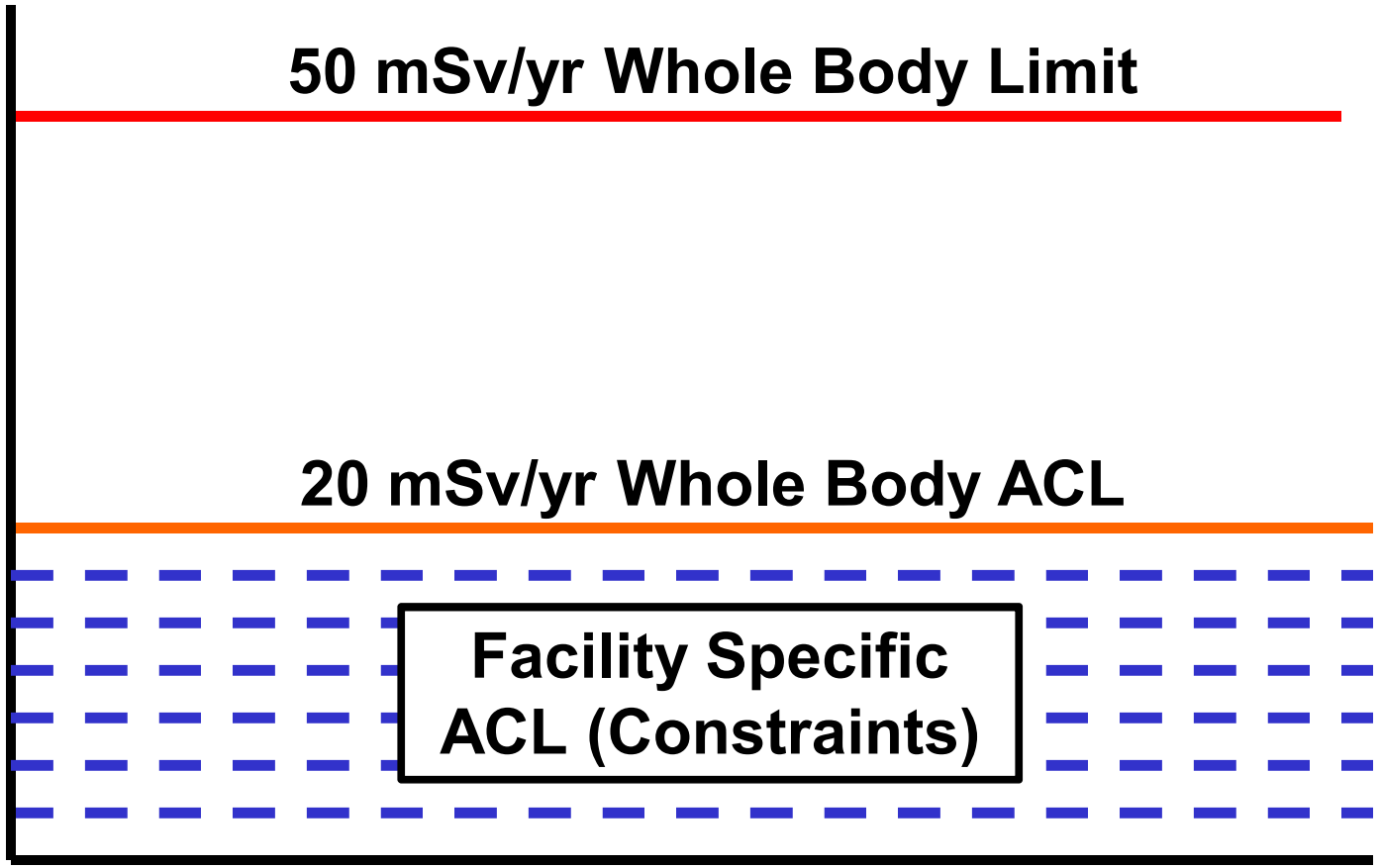
Purposes of Administrative Control Levels

Administrative control levels (ACL) are lower than the limits and are set to:

- Ensure the limits are not exceeded.
- Help reduce individual and total worker population radiation dose (collective dose).

Administrative control levels may also be called “constraints”

ACL Perspective



Dose Equivalent Limits and Administrative Control Levels

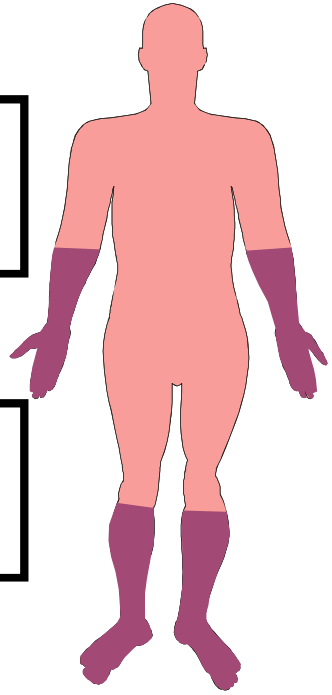
- IAEA
- Members of the Public
- Declared Pregnant Worker

Whole Body Dose Equivalent Limit

IAEA - The occupational exposure of any worker shall be controlled so that the following limits are not exceeded:

20 mSv/yr (2 rem/yr) averaged over five years

50 mSv (5 rem) in any single year

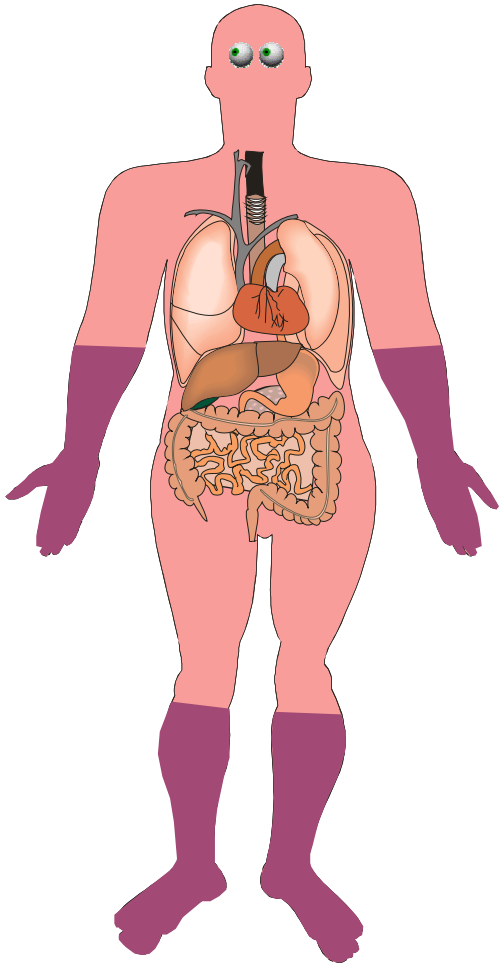


"The whole body extends from the top of the head down to just below the elbow and just below the knee."

NOTE: The whole-body dose equivalent limit is based on the sum of internal and external dose.

Limits for Other Parts of the Body

- Skin & Organs
  - 500 mSv/yr
- Extremities
  - 500 mSv/yr
- Lens of Eye
  - 150 mSv/yr



Other Dose Considerations

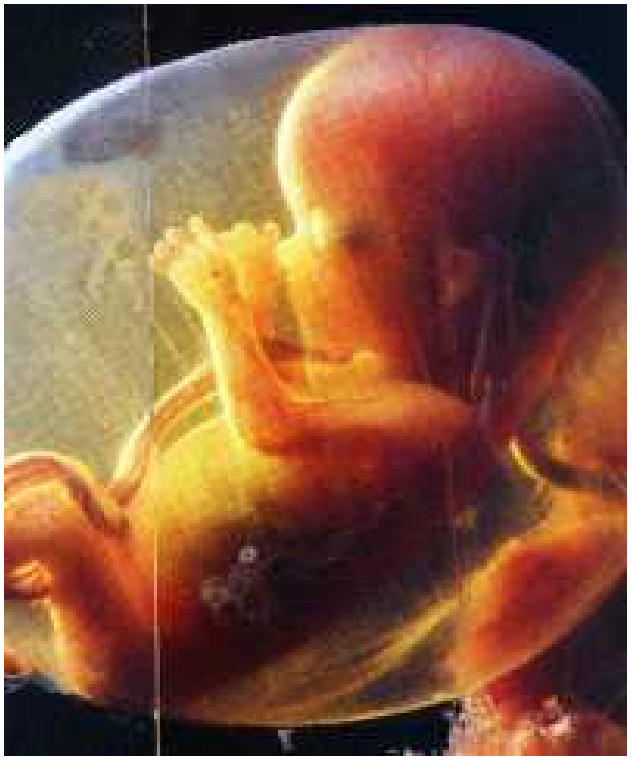
IAEA - The estimated average doses to the public shall not exceed:

- an effective dose of 1mSv in a year (100 mrem/yr)

IAEA - A female radiological worker should, on becoming aware that she is pregnant, notify the employer, in writing, that her working conditions may be modified if necessary.

Declared Pregnant Worker

The dose equivalent limit for the embryo/fetus from the period of conception to birth as a result of occupational exposure of a declared pregnant worker, is 500 mrem (5 mSv).



Lesson 3 Quiz

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Break

Lesson 4:As Low As Reasonably Achievable (ALARA)

- Concept / Policy
- Responsibilities
- Implementation

Lesson 4
Enabling Objectives

Describe exposure control concepts.

1. DESCRIBE the ALARA Concept and associated ALARA policies.
2. IDENTIFY expectations and responsibilities of management, Radiation Protection personnel, and the radiological worker in an ALARA Program.
3. IDENTIFY methods for reducing external and internal radiation dose.
4. STATE the pathways by which radioactive material can enter the body.
5. IDENTIFY methods to minimize radioactive waste.

Concept / Policy

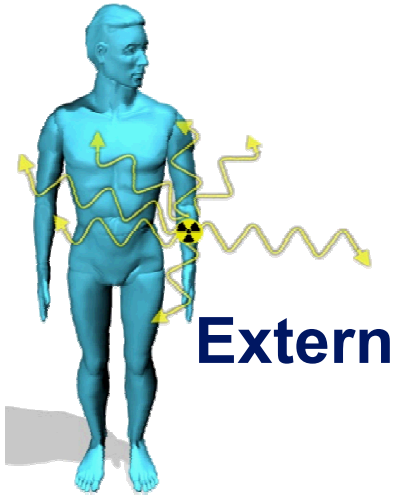
- ALARA Concept and Policy
- Operational ALARA Process

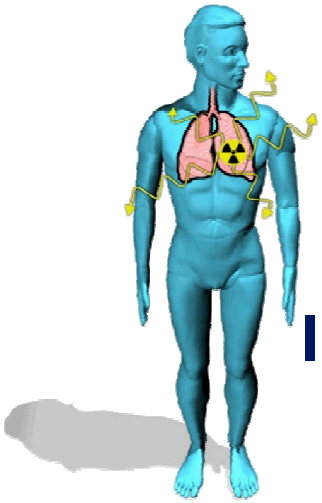
ALARA Concept

ALARA stands for As Low As Reasonably Achievable. ALARA is an approach to radiation safety that strives to manage and control doses (both individual and collective) to the work force and the general public to as low as is reasonable taking into account social, technical, economic, practical, and public policy considerations.

ALARA Concept (Cont.)

- Because some risk, however small, exists from any radiation dose, all doses should be kept ALARA.
- ALARA is the responsibility of all workers.
- ALARA includes reducing both internal and external radiation dose.





ALARA Policy

Personal radiation exposure shall be maintained As Low As Reasonably Achievable.

Radiation exposure to the work force and public shall be controlled such that:

- Radiation doses are well below limits.
- There is no radiation exposure without an overall benefit.

Operational ALARA Process

An integrated safety management approach that optimizes worker protection from **all hazards** and encompasses five discrete phases:

1. Pre-job planning
2. Hazard analysis
3. Identifying specific controls
4. Safe work performance
5. Feedback and improvement

Responsibilities

- Management
- Radiation Protection Personnel
- Radiological Worker

ALARA Responsibilities

The individual radiological worker is ultimately responsible for maintaining his/her radiation dose ALARA.

However, management and Radiation Protection personnel also play an important role in the ALARA program.

Management

- Implement ALARA practices
- Develop and achieve ALARA goals
- Ensure adequate preplanning of work and conduct of ALARA reviews
- Ensure that radiological controls and monitoring systems are as required

Management (Cont.)

- Ensure that visitors are made aware of ALARA-related responsibilities
- Ensure that required ALARA records are generated and retained
- Ensure that access to facilities by visitors is appropriately controlled

Radiation Protection Personnel

- Specify controls to maintain personnel exposure and radioactive contamination ALARA
- Provide workplace radiological monitoring services
- Assist organizations in meeting requirements of the ALARA Program
- Assist with reports and documentation
- Provide reviews for radiological safety and compliance

Expectations

Each radiological worker is expected to demonstrate responsibility and accountability.

- Accomplished through an informed, disciplined, and cautious attitude toward radiation and radioactivity.

Radiological Worker

- Understand and implement ALARA requirements
- Follow ALARA requirements as specified in work planning documents
- Participate in ALARA reviews as requested by RP personnel and their management

Implementation

- External Radiation Dose Reduction
- Internal Radiation Dose Reduction
- Radioactive Waste Minimization

External Radiation Dose Reduction

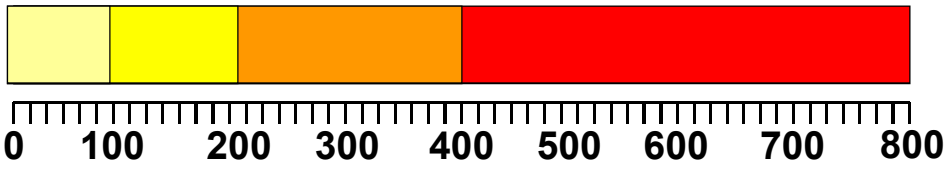
- Time
- Distance
- Shielding
- Source Reduction

Time

Minimize time in a field of radiation

100 mrem/hour field

Time in Area = _____



mrem received

Time Reduction Techniques

- Plan and discuss the task thoroughly prior to entry. Use only the number of workers actually required.
- Have all necessary tools.
- Use mockups and practice runs.
- Take the most direct path to and from the job site.

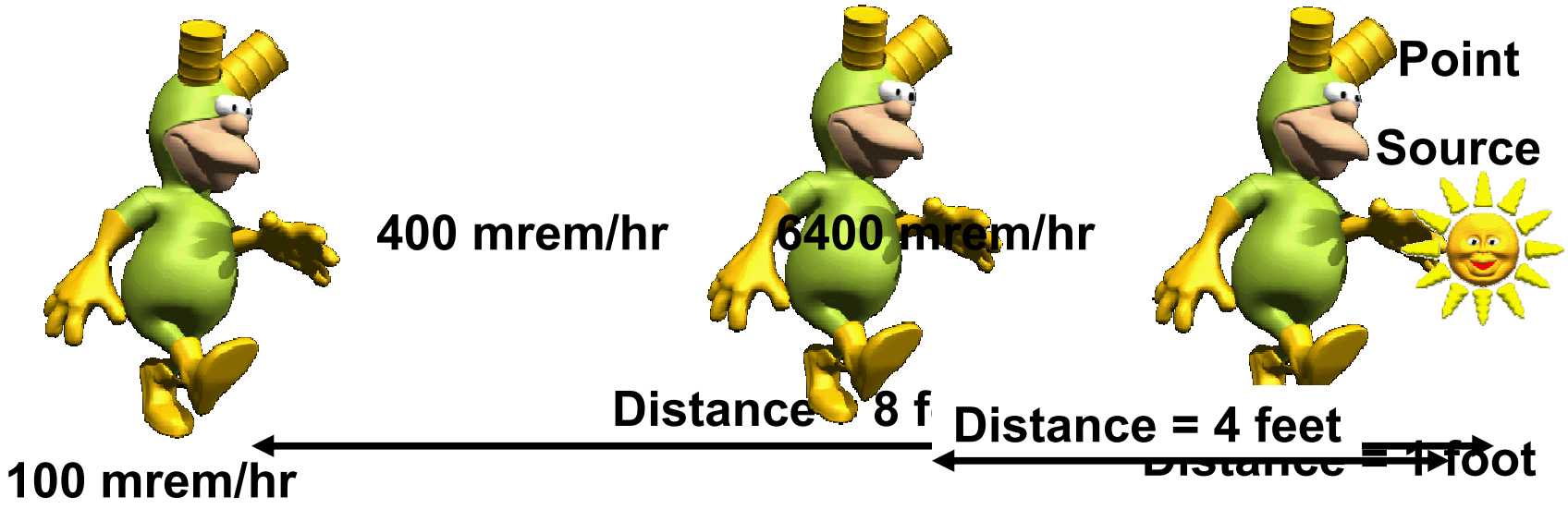
Time Reduction Techniques

- Never loiter in an area controlled for radiological purposes.
- Work efficiently and swiftly.
- Do the job right the first time.
- Perform as much work outside the area as possible.
- Do not exceed stay times.

Distance

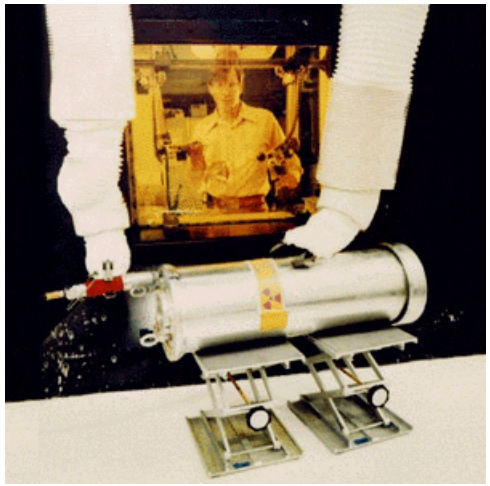
Maximize distance from a source of radiation

2 x Distance = Dose Rate / 4



Methods for Increasing Distance

- Be familiar with radiological conditions in the area
- Move to lower dose rate areas during work delays
- Use remote handling devices when possible

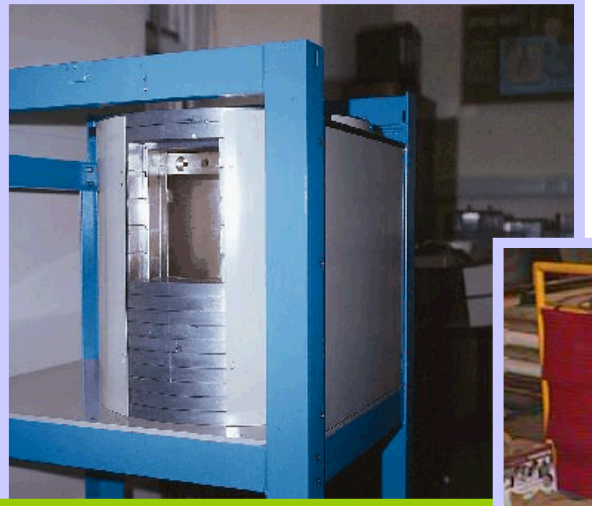


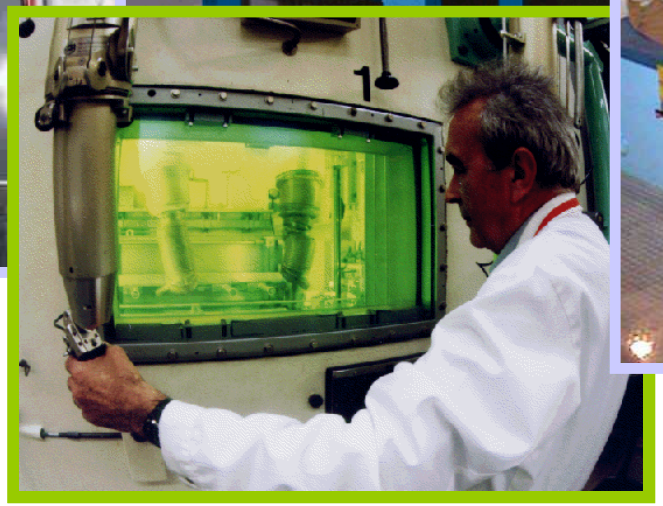
Use of Shielding

Use shielding whenever possible

- Take advantage of permanent shielding such as non-radiological equipment / structures.
- Use shielded containments when available.
- Wear safety glasses/goggles to protect your eyes from beta radiation, when applicable.

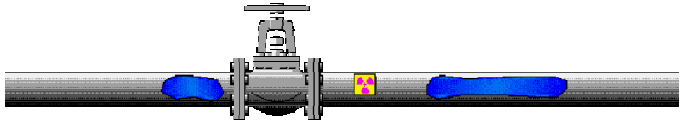
Shielding Examples





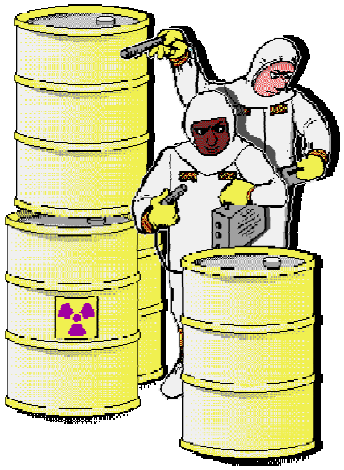
Source Reduction Methods

- Flush radioactive systems



- Decontaminate

- Move high radiation sources out of the work area
- Wait for decay of short-lived isotopes



LESSON LEARNED
Radiation Exposure Reduction

Electronic dosimeters can aid significantly in exposure reduction even in low dose rate fields

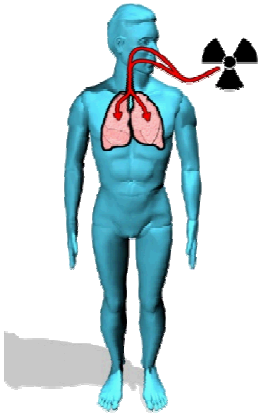
Electronic dosimeters (ED's) can be set to "chirp" when radiation is present

Chirp rate increases with increasing radiation levels

Increasing chirp rate prompts workers to spend less time in these areas

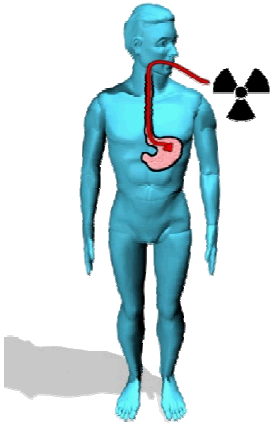
Internal Exposure Pathways

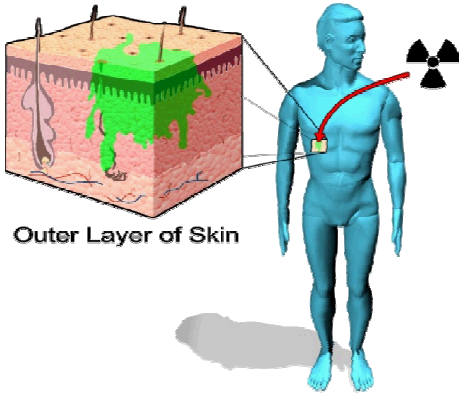
Internal dose results from radioactive material being taken into the body through:



Inhalation

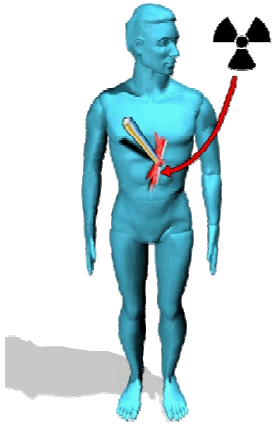
Ingestion





Skin Absorption

Wound Absorption



Methods to Reduce Internal Exposure

- Wear respiratory protection when qualified
- Do not eat, drink, smoke, chew or touch face in contaminated areas
- Seal the openings of protective clothing with tape
- Keep wounds protected and clean

Respiratory Protection

Respiratory protection should be considered when entering an area where airborne contamination is likely.

Respiratory Protection Equipment

Air-purifying respirators

- Filtering facepiece
- Half-face
- Full-face negative pressure
- Powered Air-purifying

Atmosphere-supplying respirators

- Self-contained Breathing Apparatus (SCBA)
- Supplied-air respirator (Airline)

Respiratory Protection Best Practices

- User trained to use respiratory protection equipment
- User medically approved for use
- User fit tested on make, model, size
- Respirator facepiece individually assigned
- Respirator inspected periodically
- Respirator maintained cleaned and sanitized
- User clean shaven

Radioactive Waste

One of the potential consequences of working with radioactive materials is the generation of radioactive waste.

Radioactive Waste Minimization

- Minimizing waste will minimize personnel exposure from handling and processing
- Minimize the materials used for radiological work
  - Take only tools and materials needed into areas controlled for radiological purposes
  - Unpack equipment and tools in a clean area
  - Use tools and equipment that are identified for radiological work
  - Use only the materials required to clean

Radioactive Waste Minimization (Cont.)

- Segregate radioactive from nonradioactive waste
- Segregate compactable material from non-compactable material
- Minimize the amount of mixed waste generated. (Mixed = radioactive + hazardous)
- Use good housekeeping techniques

Lesson 4 Quiz

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Break

Lesson 5:
Personnel Monitoring

- **External Dosimetry**
- **Internal Monitoring**
- **Dose Records**

Lesson 5
Enabling Objectives

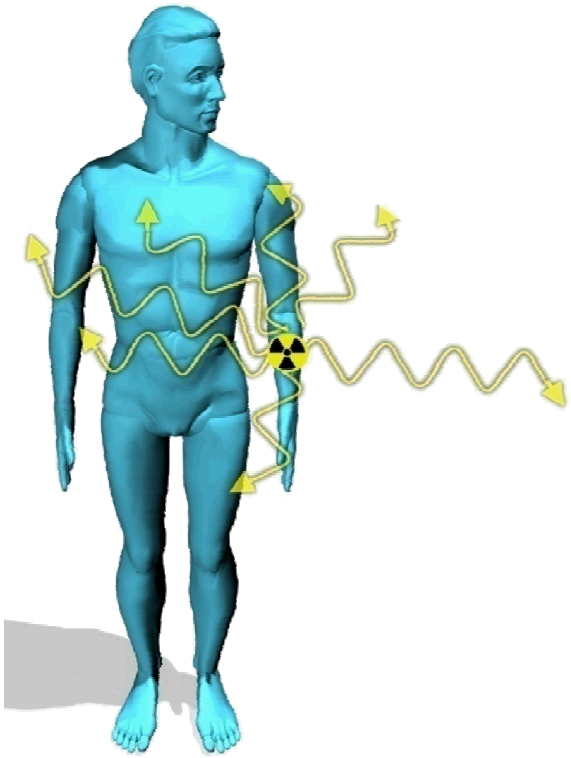
Discuss personnel monitoring programs

1. DESCRIBE the use and purpose of external dosimeter devices.
2. DESCRIBE the use and purpose of internal monitoring methods.

External Dosimetry

- External Exposure
- Personnel Monitoring Devices
- Dosimetry Requirements
- Workforce Responsibilities
- Dosimetry Use & Care
- Response to Unplanned Dosimetry Situations

External Exposure



Radiation can bombard the body from sources within the body and from sources outside the body. External dosimetry is used to monitor exposure to radiation emanating from sources external to the body.

Personnel Monitoring Devices

Various types of dosimetry devices are used to measure personnel dose received from exposure to external sources of radiation:

Whole-Body Dosimeter

Extremity Dosimeter

Electronic Dosimeter

Whole-Body Dosimeter

The Thermoluminescent Dosimeter (TLD) is still widely used to determine occupational dose received from external sources.

The Optically Stimulated Luminescence Dosimeter (OSLD) is the latest, most reliable, most accurate dosimeter available today.

These dosimeters typically measure gamma, x-ray, neutron, and beta radiation dose equivalent

Extremity Dosimeters

- Used to supplement, not replace, whole-body dosimetry
- Normally consists of a TLD or OSLD chip embedded in a finger ring
- One normally issued – worn on the most exposed extremity
- One per extremity can be issued – to be worn separately when in use

- Worn under protective clothing such as gloves

Electronic Self-Reading Dosimeters

- Provides immediate, real-time, running estimate of whole-body dose received
- Provided on an as-needed basis by Radiation Protection personnel
- Sensitive to X-ray and gamma radiation
- Capable of displaying dose OR dose rate measurements
- Capable of providing dose AND/OR dose rate alarms

Typical Electronic Dosimeter

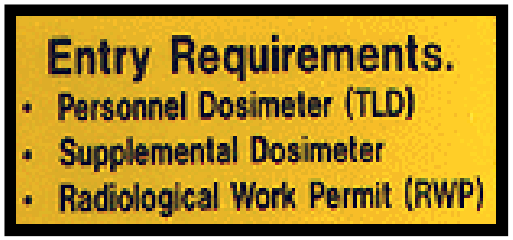
Wearing Electronic Dosimeter (ED)

- Wear with the clip facing away from the body
- Wear self-reading dosimeters in close proximity to the whole-body dosimeter
- Do not wear self-reading dosimeters directly over whole body dosimeters

Dosimetry Requirements

Personnel dosimetry is typically required:

- When radiological workers are likely to receive ≥ 1 mSv whole body in a year from external sources
- When entering radiation areas
- When entering controlled areas where a dosimetry requirement is posted



Workforce Responsibilities

Personnel who are required to have dosimetry are responsible for:

- Complying with dosimetry requirements
- Participate in bioassays, whole-body counts, etc.
- Properly wearing dosimetry and personal air samplers
- Immediately reporting the loss, damage or contamination of dosimeters
- Notifying RP Personnel if scheduled for or have had a nuclear medicine procedure.

Lesson Learned
- Travel Guidance -

- Newly installed airport X-Ray equipment can cause significant exposure to dosimeters.
- Avoid taking dosimeters on travel.
- When dosimeters are taken on an airplane, place them in carry-on bags, not checked baggage.

Electronic Dosimetry Anomaly

- ✓ **Stop** and place work in a safe configuration.
- ✓ **Alert** co-workers of the problem and that you are leaving the area. Recommend that they check their dosimeters.
- ✓ **Exit** the area immediately.
- ✓ **Notify** RP personnel and management as soon as practicable.

Note: RP personnel may choose to perform a dose reconstruction and/or initiate a work restriction.

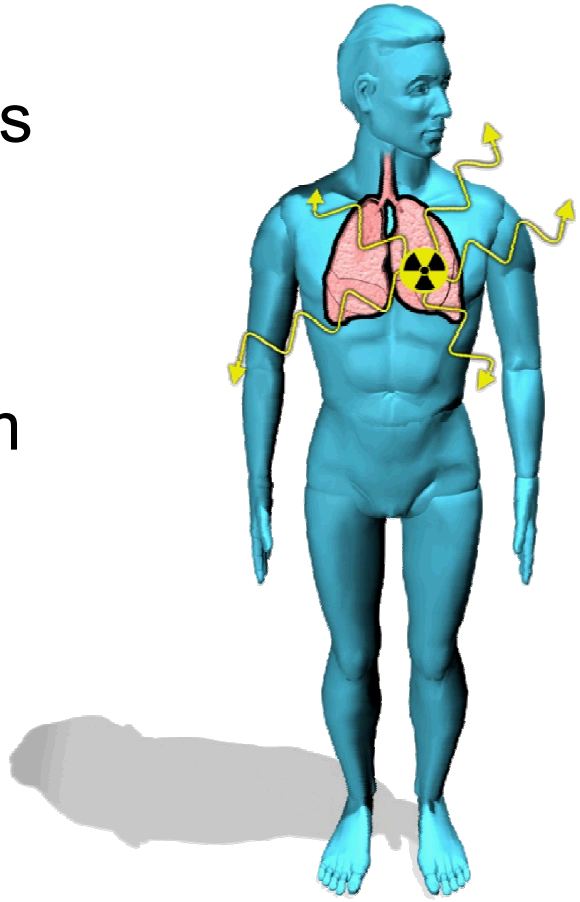
Internal Monitoring

- Internal Exposure
- Internal Monitoring Purpose
- Internal Monitoring Process
- Internal Monitoring Methods
- Obtaining Dose Records

Internal Exposure

If radioactive material is taken into the body, radiation bombards the body from the inside out.

Internal monitoring is used to monitor radiation emanating from sources internal to the body.

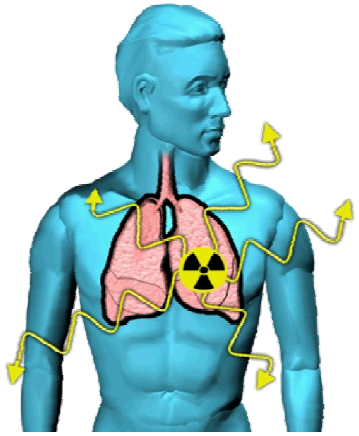


Internal Monitoring Purpose

- Quality Control check for workplace monitoring
- Determination if medical intervention is necessary
- Determine if dose limits have been approached or exceeded

Internal Monitoring Process

- Measure amount of radioactive material present inside the body
- Calculate an internal dose
- Conducted to monitor workers for internal exposure to fission / activation products, transuranics, tritium, etc., as needed

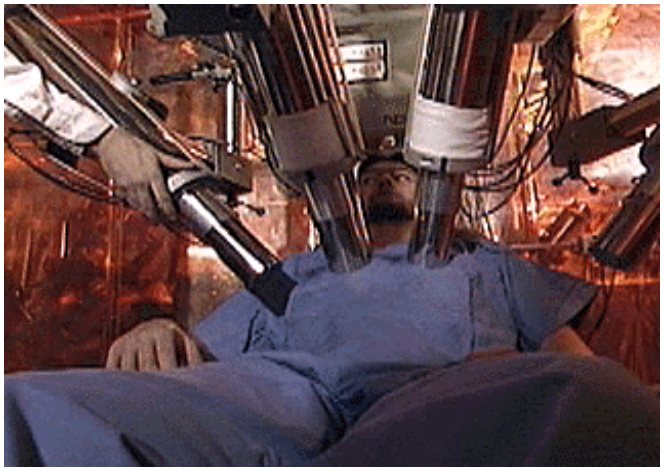


Internal Monitoring Methods

- Whole-body counting
- Bioassay

Whole-Body Counting

- Sample stays inside the body
- Whole-body counting is the standard internal monitoring method used for most nuclear power plant applications



Bioassay

- Sample(s) provided to RP Personnel
- Examples:
  - Urine (most common)
  - Feces

Internal Monitoring Requirements

The workforce provides bioassay samples or submits to a whole body count when:

- They have received previous internal exposure from another site
- They have received unintentional internal exposure or possibly a radiological intake
- A personal air sample indicates internal exposure ≥ 10 mrem
- Required on a Technical Work Document (TWD)
- Terminating employment

Personal Air Sampling

Radiation Protection may require the use of a personal air sampler. The sampler is used to sample the air in the breathing zone for radioactive material. (Also called Lapel Air Sampler)

Lesson 5 Quiz

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Break

Lesson 6: Radiological Work Planning & Control

Lesson 6
Enabling Objectives

Describe radiological work control methods and processes

1. IDENTIFY various controls used to maintain radiation exposures ALARA.
2. DESCRIBE work control documents for radiological work activities.
3. DESCRIBE common area designations used for radiological control purposes.
4. IDENTIFY general responsibilities for working in radiological controlled areas.
5. EXPLAIN the purpose and use of personnel contamination monitors.

Radiological Work Planning

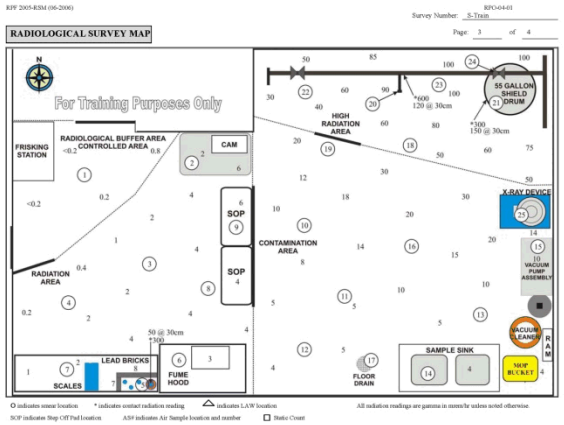
Radiological work planning:

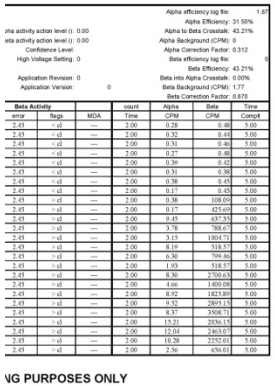
- Ensures radiological work is conducted in a safe and compliant manner
- Engages assistance of Radiation Protection
- Ensures ALARA is considered in work planning

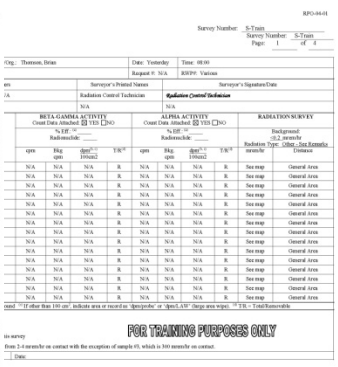
NOTE: Consider other Hazards associated with the work, not just radiological.

Radiological Surveys

- Qualified Radiological Control Technicians perform and document radiological surveys
- Used to establish radiation protection requirements



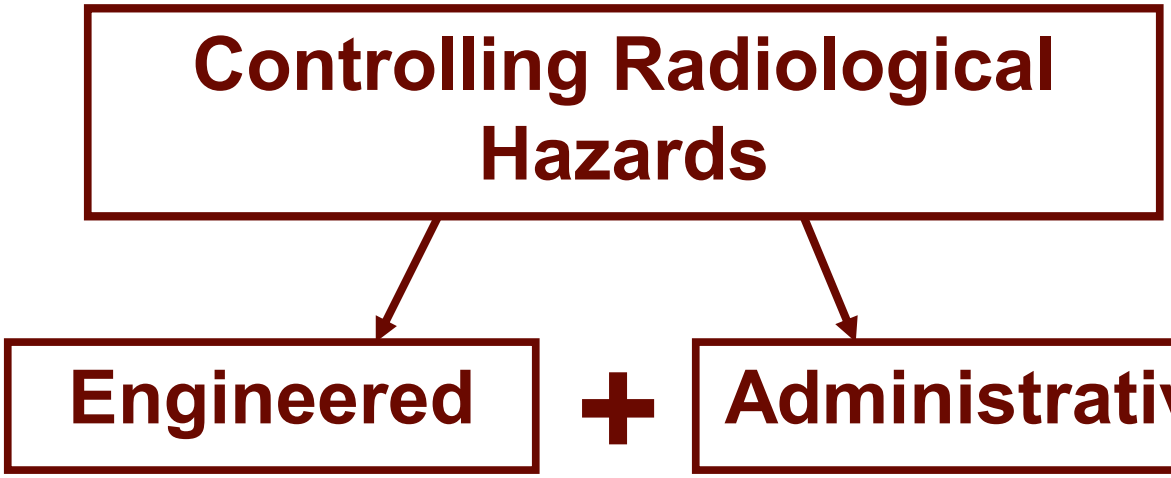




A Combination of Controls

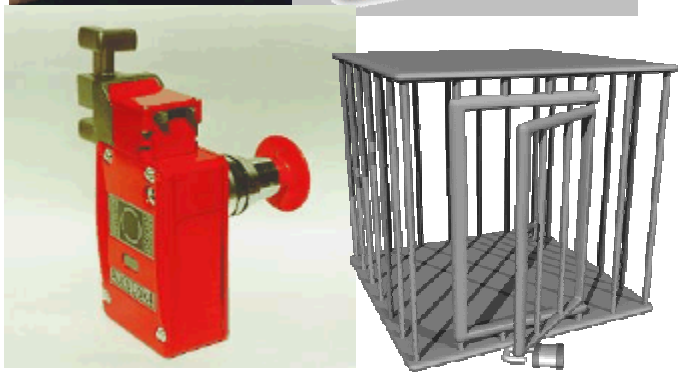
A combination of controls ensures that:

- Dose limits are not approached or exceeded
- Contamination is controlled at the source
- Planned ALARA measures are implemented



Engineered Controls

Radiation exposure in radiologically controlled areas is maintained ALARA *primarily* through facility established engineered (physical) controls.



- Installed Shielding
- Containment Systems
- Facility Design
- Safety Interlocks
- Key or Code Controlled Locks

Engineered Control Example
- Containments -

Total Containment – used for higher risk activities

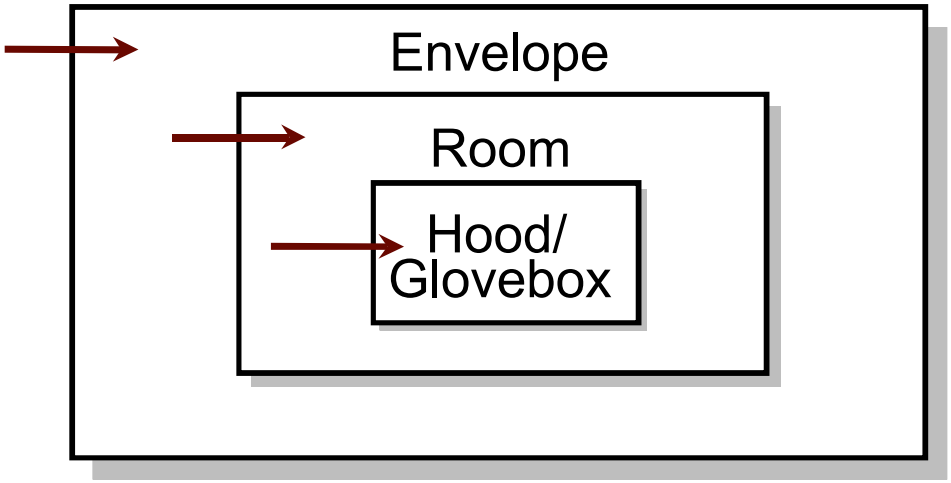
Partial Containment – used for lower risk activities

Type of containment to be used is determined by:

- Activity concentration
- Physical form of contaminant
- Task to be performed

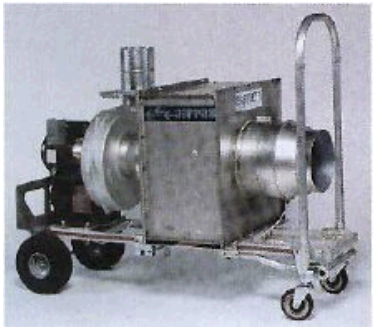
Engineered Control Example
- Facility Airflow -

Controlling airflow is a preferred method for controlling contaminants.



Airflow should be from areas of LEAST to MOST contamination.

Engineered Control Example
- Local Exhaust -



Local exhaust ventilation removes airborne radioactivity regardless of release rate or chemical or physical form.

These techniques use relatively low volume rates compared to normal ventilation requirements.

Administrative Controls

Administrative controls are typically used in combination with engineering controls when engineering controls alone are impractical.

Examples:

- Managing job rotation, work assignments, etc.
- Work planning and control documents
- Work-related training and certifications
- Radiological postings
- Pre-job, plan of the day, and post-job briefings

Radiological Postings

An administrative control designed to:

- Alert personnel to the presence of radiation or radioactive materials
- Inform workers of radiological conditions to aid in minimizing exposure
- Provide radiological area entry requirements
- Help prevent the spread of contamination

Radiological Postings (Cont.)

Each sign will have some type of warning label associated with the radiological area defined.

The warnings used are:

- Caution
- Danger
- Grave Danger

Posting Standard

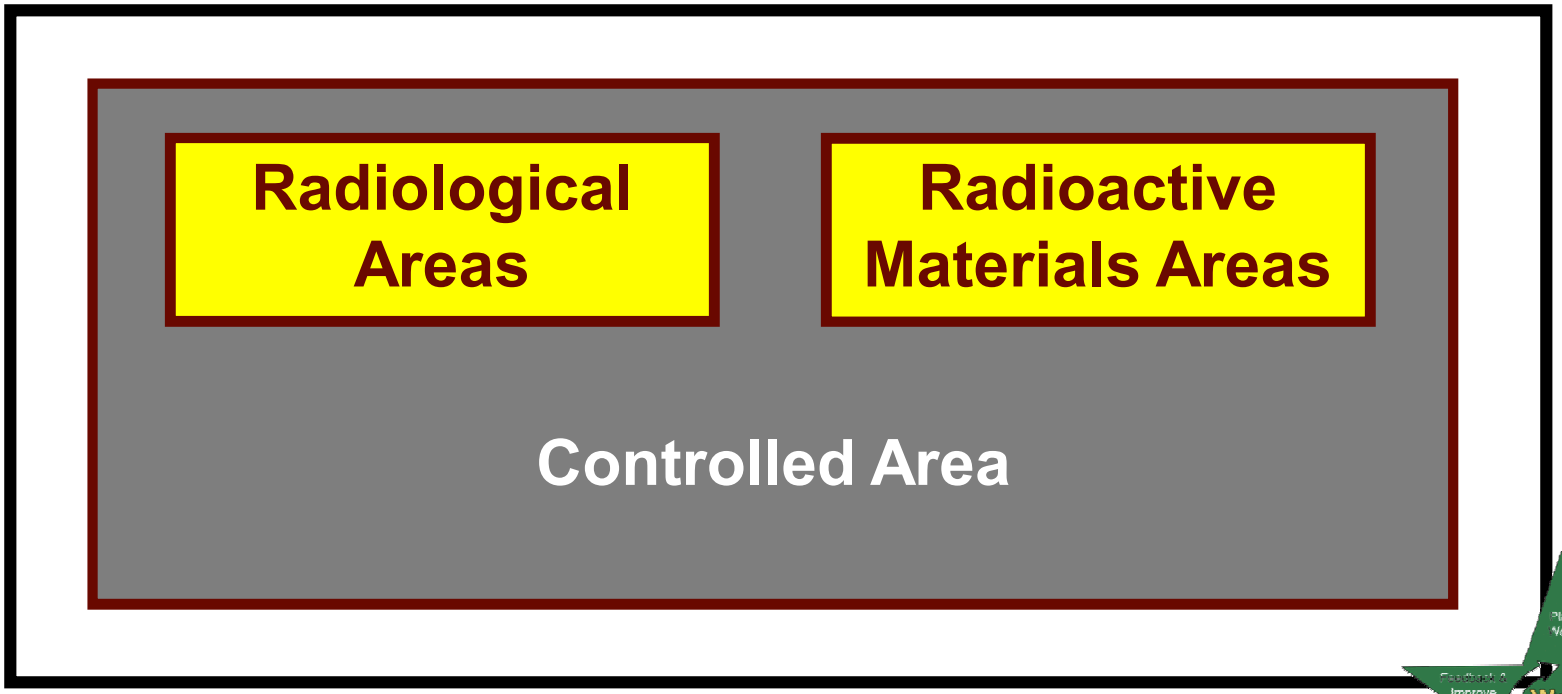
All signs and labels bear the standard radiation trefoil in magenta or black imposed upon a yellow background.

Rope, tape, chain, or similar barrier material used is yellow and magenta.

Example

Controlled Area Layout

Radiological Areas and Radioactive Material Areas are contained within Controlled Areas



Example

Radiological Areas

Any area within a controlled area which is posted as a:

Radiation

- Radiation Area
- High Radiation Area
- Very High Radiation Area

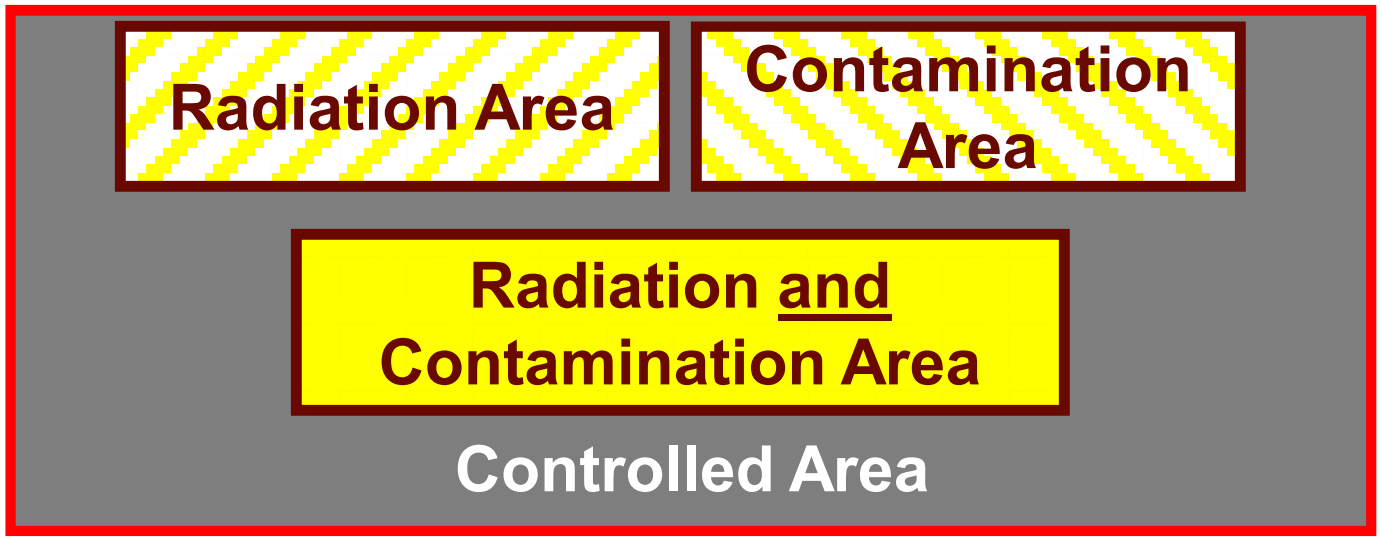
Contamination

- Contamination Area
- High Contamination Area
- Airborne Radioactivity Area

Example

Radiological Area Layout

Radiological Areas are contained within Controlled Areas and are based on existing or potential radiation and contamination levels



Example

Radiation Area

Any area, accessible to individuals, in which radiation levels could result in an individual receiving a deep dose equivalent in excess of 50 μSv (5 mrem) in 1 hour at 30 cm from the radiation source or from any surface that the radiation penetrates

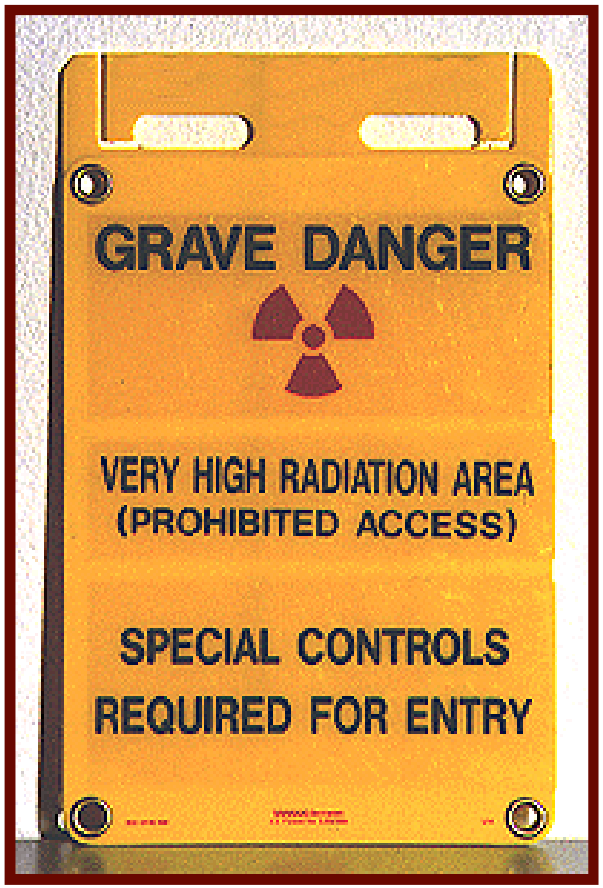
High Radiation Area

Example

Any area, accessible to individuals, in which radiation levels could result in an individual receiving a deep dose equivalent in excess of 1 mSv (100 mrem) in 1 hr at 30 cm from the radiation source or from any surface that the radiation penetrates.

Note: Caution or Danger may be used.

Very High Radiation Area



Example

Any area, accessible to individuals, in which radiation levels could result in an individual receiving an absorbed dose in excess of 5 gray (500 Rad) in 1 hour at 1 meter from a radiation source, or from any surface that the radiation penetrates

Contamination Area

Example

Any area, accessible to individuals, where removable surface contamination levels exceed or are likely to exceed the removable surface contamination values specified in regulatory requirements but do not exceed 100 times those values

High Contamination Area

Example

Any area, accessible to individuals, where removable surface contamination levels exceed or are likely to exceed 100 times the removable surface contamination values specified in regulatory requirements

Note: Caution or Danger may be used

Airborne Radioactivity Area

Example

Any area, accessible to individuals, where the concentration of airborne radioactivity, above natural background, exceeds or is likely to exceed the derived air concentration values listed in regulatory requirements.

Note: Caution or Danger may be used

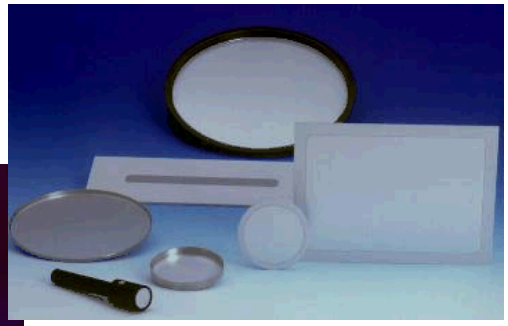
Radioactive Material Area

Example

Any area within a controlled area, accessible to individuals, in which items or containers of radioactive material exist and the total activity of radioactive material exceeds the applicable values provided in regulatory requirements.

Radioactive Material

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



Example

Radioactive Material Examples

Example

Radioactive Material Labeling

Example

- All items or containers of radioactive material are labeled.
- Labels are durable and contain the standard radiation warning trefoil and the words “Caution (or Danger), Radioactive Material”.

Labeling (Cont.)

Labels must provide sufficient information to permit individuals handling or using the containers, or working in the vicinity of the containers to take precautions to avoid or minimize exposures.

Labels must be clearly visible on items or containers.

Supplemental Postings

- Soil Contamination Area
- Underground Radioactive Material Area
- Fixed Contamination Area
- Hot Spot

Soil Contamination Area

This area contains surface or subsurface soil contamination that exceeds limits

Underground Radioactive Material Area

Example

Established to indicate the presence of underground items that contain radioactive materials such as pipelines, radioactive cribs, covered ponds, inactive burial grounds, and covered spills

Fixed Contamination Area

An area or equipment that contains radioactive material that cannot be easily removed from surfaces by nondestructive means, such as wiping, brushing, or laundering

Example

Hot Spots

A radiological area where a specific spot has a dose rate five times or more than the general area dose rate and the dose rate is greater than 1 mSv/hr (100 mrem/hr), on contact

Example

Radiological Work Planning Documents

Purpose - to provide information to individuals who will focus on completion of a specific task involving potential radiological hazards.

Address all aspects of the work:

- Job description
- Hazard communication
- Identification of controls (as well as)
- Specific instructions for the work to be performed.

Radiological Work Documents

Must include:

- A description of the work activity with detail commensurate with the radiological hazards
- Sign-in sheets
- Identification of associated work hazards
- ALARA Review Requirements
- Specific radiological training requirements
- Pre-job briefing and worker sign-in frequency
- Radiological work controls including…….

General Work Control Requirements & Responsibilities

Radiological workers are responsible for:

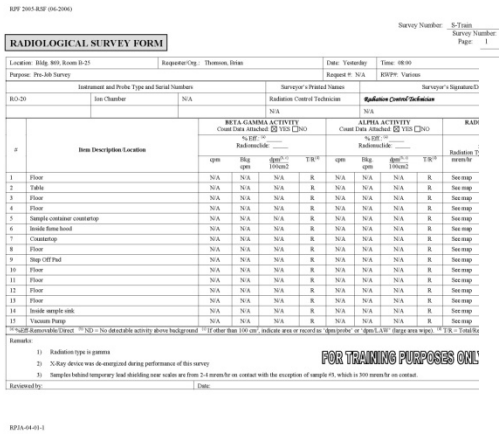
- Complying with radiological controls identified in work control documents.
- Terminating and placing in a safe configuration any activity deemed unsafe or outside the scope of the planned radiological work.
- Notifying the appropriate RP Personnel and management when the scope of work changes or there is a need to deviate from the controls imposed by a work control document.

Defining Scope Change

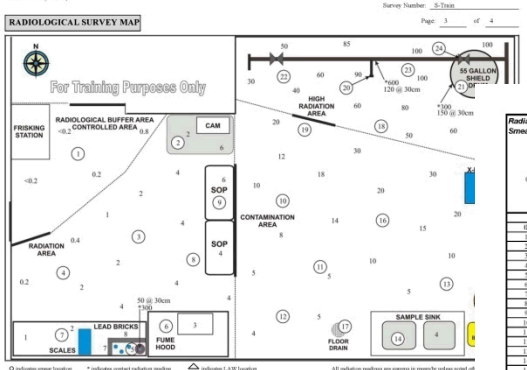
- Changing the scope of work voids work control documents. Controls may become inadequate.
- The following could change the scope of work:
  - Time to do the job is longer
  - A new hazard is introduced
  - A physical barrier is added or removed
  - A different tool or piece of equipment needs to be used
  - Work or materials must be moved to a different location
  - Other……..

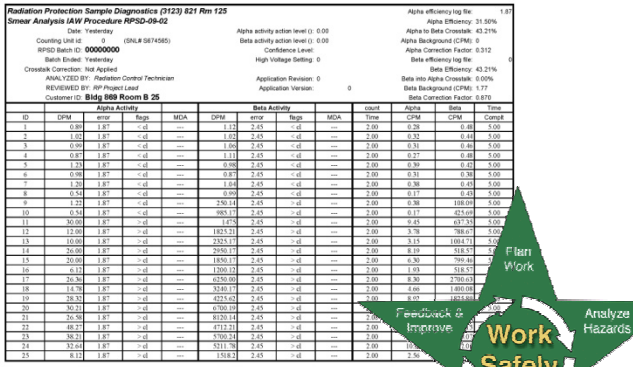
Entry Requirements & Responsibilities (Cont.)

- Resolving questions concerning your work and related documents prior to entry
- Being aware of radiological conditions in the work area (review surveys)


RADIOLOGICAL SURVEY FORM

FOR TRAINING PURPOSES ONLY

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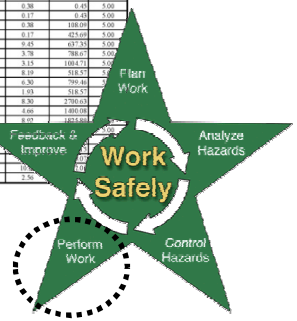


Entry Requirements & Responsibilities (Cont.)

NOT moving or modifying:

- Postings,
- Barricades,
- Shielding,
- Boundaries, or

NOT reaching across radiological boundaries unless authorized to do so.

Entry Requirements & Responsibilities (Cont.)

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

- unnecessary or excessive exposure
- serious injury
- disciplinary action
- spread of contamination

Work Requirements & Responsibilities

- Performing only activities described in the scope of the applicable work control document
- Contacting RP personnel at designated steps where monitoring must be performed
- Ensuring that the evidence of hold point surveys is completed
- Implementing ALARA practices (time, distance, shielding, source reduction)
- Wearing dosimetry according to instructions

Work Requirements & Responsibilities (Cont.)

NOT eating, drinking, chewing gum, or applying cosmetics while in:

- Airborne radioactivity areas
- Areas established for contamination control
- Radioactive material areas
- Soil contamination areas (drinking may be allowed in designated areas)

Exit Requirements & Responsibilities

- Upon exiting an area associated with contamination, monitoring yourself in accordance with posted instructions.
- Signing-out upon exit from any area covered by the provisions of a work document, when required.
- Adhering to posted exit requirements.

Personnel Monitoring for Contamination (Frisking)

- Performed to detect contamination on clothing, skin and/or hair
- Must be done correctly and as soon as possible following exit from an area but prior to washing, showering, or exiting controlled areas.

Hand-Held Frisking Equipment

Smaller round probe(s) for beta

Larger rectangular probe(s) for alpha (some models work for alpha <u>and</u> beta)

Automated Frisking Equipment (PCM-1B)

Frisking Procedure

Visually inspect frisker to verify that:

- instrument is on
- instrument is on the lowest scale
- audio output can be heard

Frisking Procedure (Cont.)

- Verify background radiation level is low
- Prior to picking up probe, frisk one hand by moving hand across active area of probe.
- Hold the probe close to surfaces being frisked (within 1 cm)
- Move probe slowly 2 to 5 cm per second

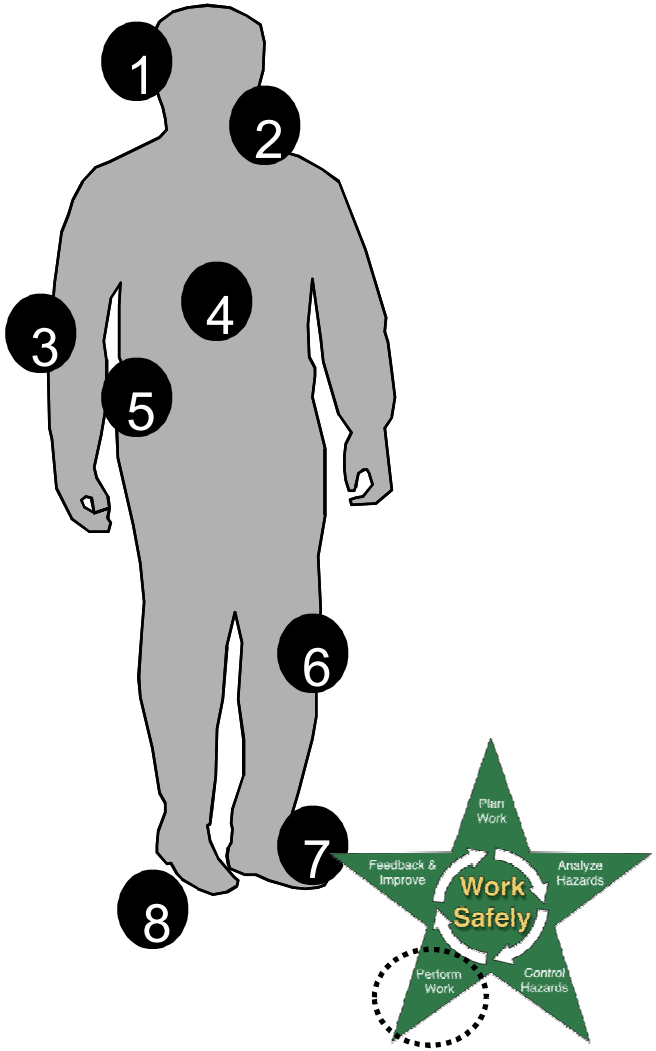
Frisking Procedure (Cont.)

If the audible output increases, hold the probe over the area for 10-15 seconds to provide adequate time for instrument response.

- After frisking the first hand, frisk the other hand.
- If the frisk of the second hand does not indicate the presence of contamination, complete a whole-body frisk.

Recommended Order

1. head (pause at mouth) *after completion of hands
2. neck/shoulders
3. arms (pause at elbows)
4. chest/abdomen
5. back/hips/seat of pants
6. legs (pause at knees)
7. shoe tops
8. shoe bottoms



Frisking Procedure (Cont.)

- Return probe to holder, recheck hand used to hold the probe, and leave the area.
- Position the probe so that the next person can frisk one hand without touching the probe.
- If contamination is indicated,
  - notify RP Personnel and
  - remain at the frisking station.

Conducting Radiological Job Reviews

- Post-job reviews are conducted when specific events are triggered (individual or collective dose, stop work, etc.)
- Reviews may result in the need to revise or replace a work control document
- Individual radiological workers may be asked to participate in post-job review meetings.

Lesson 6 Quiz

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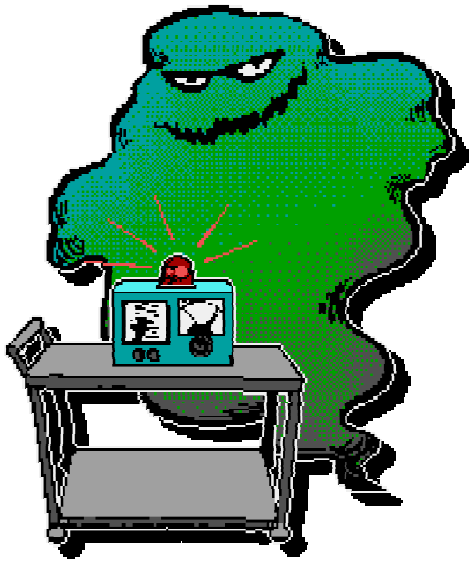
Break

Lesson 7
Radiological Emergencies



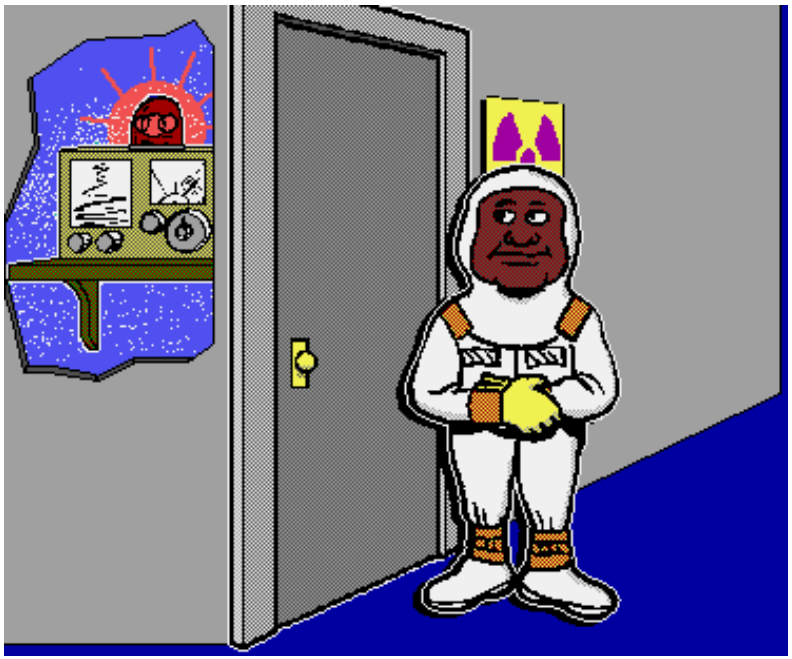
- Emergency Alarms and Responses
- Disregard for Radiological Alarms
- Radiological Emergency Situations and Appropriate Responses
- Considerations in Rescue and Recovery Operations

Lesson 7
Enabling Objectives

Identify the appropriate responses to radiological events

1. STATE the types and purpose of emergency alarms.
2. IDENTIFY the correct responses to emergencies and/or alarms.
3. STATE the possible consequences for disregarding radiological alarms.
4. DISCUSS emergency radiation dose limits.

Radiological Events



- Operational Emergency
- Non-emergency

Personnel should respond quickly to radiological events to protect personnel and property, mitigate the incident, and maintain exposures ALARA.

Operational Emergency

An unplanned, significant event or condition that requires time-urgent actions from emergency response resources to ensure the:

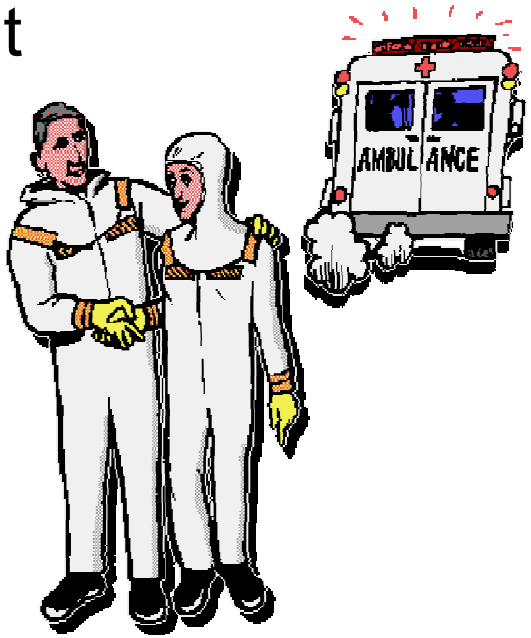
- Health and safety of the workforce and the public
- Protection of the environment
- Security of operations

CALL Emergency Hotline

Non-Emergency

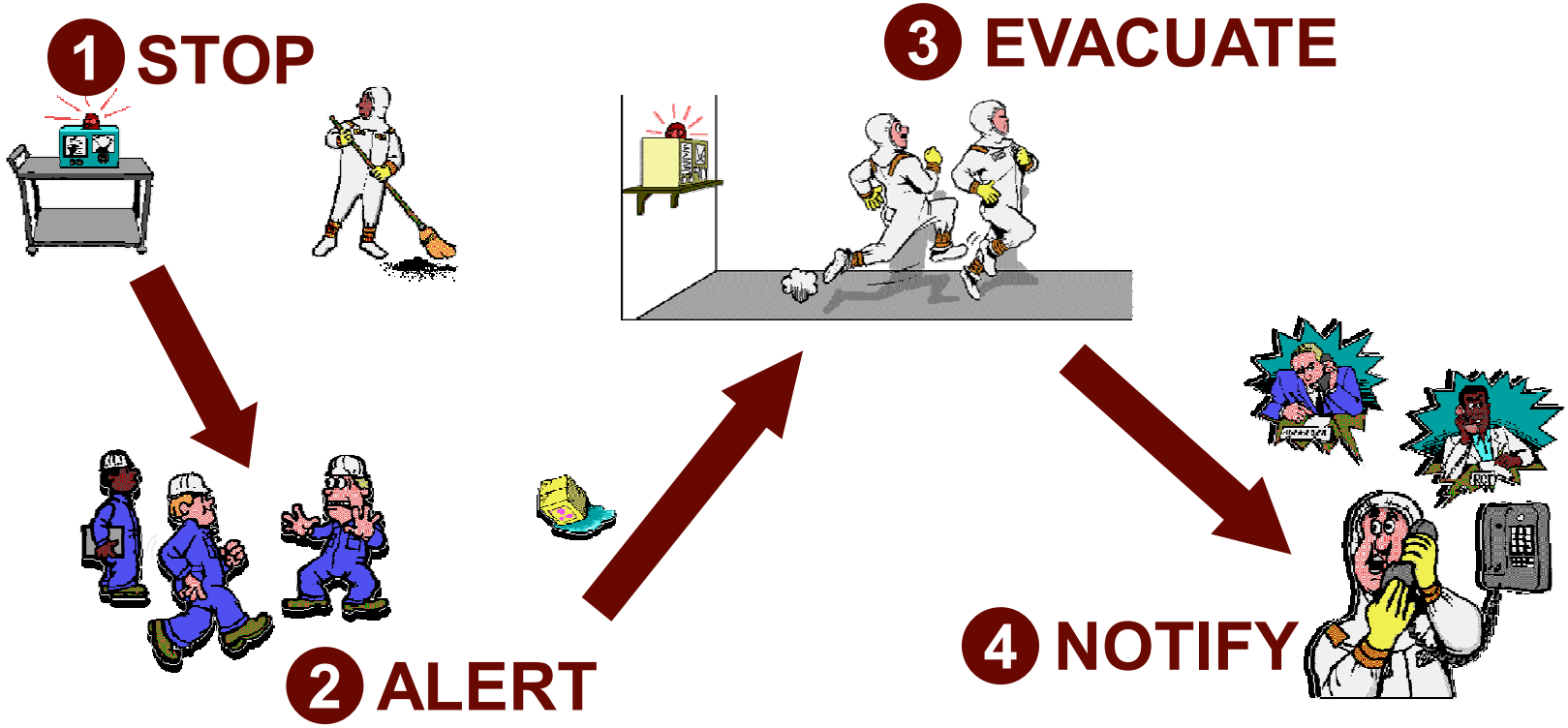
An unplanned situation that does not pose imminent danger or require immediate assistance, but could affect:

- Health and safety of the workforce and the public
- Protection of the environment
- Security of operations

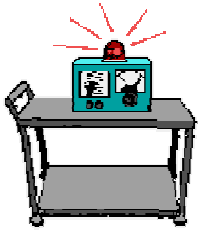


Radiological Event Response

Personnel involved in a radiological event shall take the appropriate general, initial actions documented below to the extent deemed safe and that they are comfortable with doing so:



1 STOP



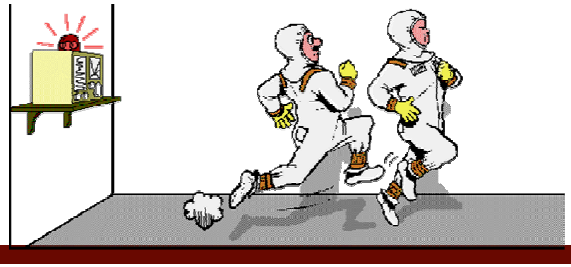
Stop work and contain the radiological hazard, if possible, employing actions such as the following, unless such actions are imminently dangerous:

- Attempt to stop spills by righting containers.
- Turn off equipment or stop operations that may be generating airborne hazards.
- Secure ventilation in the case of potential airborne hazards except ventilation known to be HEPA-filtered.
- Shut down radiation-generating equipment or shielding sources that may be causing high radiation levels.
- Note the readings of any work area radiation area monitors and continuous air monitors, if possible.

2 ALERT

- Alert other personnel in the affected area.
- Some personnel in the area may not hear the alarm.
- Some personnel in the area may not understand the seriousness of the situation.
- Some personnel may fail to take the appropriate actions in response to the alarm.

3 EVACUATE



Evacuate the immediate affected area and do the following during evacuation:

- Take actions to minimize the spread of contamination during evacuation, if possible.
- Remain at the designated location to aid with the accounting for personnel accountability and to facilitate monitoring by RP personnel.

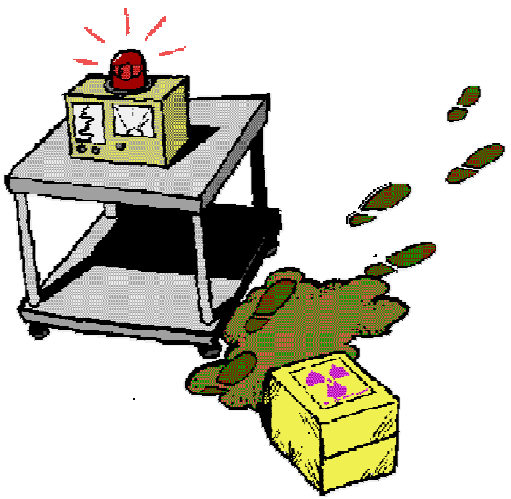
Note: Evacuation in response to a work area radiological alarm is standard procedure pending subsequent evaluation of the hazard.

4 NOTIFY

- Notify the Incident Commander (IC).
- Notify RP personnel and responsible management as soon as practical.

Emergency Phone Numbers	

Emergency Alarms



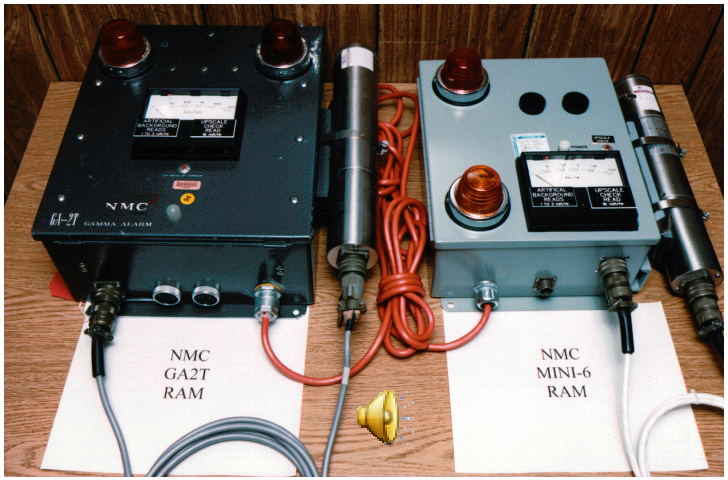
- Various radiological monitoring systems are present
- Personnel must be able to identify the equipment and alarms, and respond appropriately.

Basic Types:

Radiation Area Monitor

Continuous Air Monitor

Radiation Area Monitor (RAM)



- Monitors radiation levels in an area
- Installed in locations with potential for unexpected increases in dose rates

Primary Response Consideration

Minimize Radiation Exposure

Response to RAM Alarm

- ✓ Stop work and place in a safe condition
- ✓ Alert others
- ✓ Evacuate the affected work area
- ✓ Notify the emergency responders immediately
- ✓ Check self-reading dosimetry
- ✓ Account for all affected personnel
- ✓ Isolate the work area
- ✓ Wait for RP personnel to arrive

Continuous Air Monitor (CAM)

- Samples/monitors airborne radioactivity
- Installed in locations with potential for airborne

Primary Response Considerations

Minimize Inhalation

Limit The Spread Of Airborne

Response to CAM Alarm

- ✓ Stop work and place in a safe condition
- ✓ Alert others
- ✓ Evacuate the affected work area
- ✓ Notify emergency responders immediately
- ✓ Start HEPA filtered ventilation (if available)
- ✓ Account for all affected personnel
- ✓ Isolate the work area
- ✓ Wait for RP personnel to arrive

Consequences of Disregarding Alarms

- Personnel overexposure
- Uncontrolled spread of contamination
- Equipment damage
- Personnel injury
- Disciplinary action, up to and including dismissal

Response to Spills of Radioactive Material

- Immediately notify response team and follow the SWIMS procedure:
  - **S**top the spill
  - **W**arn others around you
  - **I**solate the area if possible (boundaries)
  - **M**inimize your own exposure to contamination and radiation
  - **S**ecure unfiltered ventilation, as appropriate
- Follow directions from the response team

Leaking or Damaged Radioactive Source

- Take actions to minimize the spread of contamination, such as controlling access
- Direct handling of the source should be kept to a minimum
- Notify RP personnel who will remove the source from service

Lost or Stolen Radioactive Material

- Look for the material with the assistance of RP personnel.
- Advise management of status and potential hazards.

Radioactive Material in an Uncontrolled Area

Instruct someone else to contact RP personnel while controlling access

Assist RP personnel in establishing and posting a controlled area if the material cannot immediately be removed

Response to Serious Injuries in Controlled Areas

- Call Emergency Responders
- Administer first aid as appropriate
- Follow the instructions of emergency personnel who respond to the call

The Immediate Health Of The Person Is Primary. Radiation Protection Concerns Are Secondary.

Considerations in Rescue & Recovery Operations

- Exposure to high levels of radiation may be necessary during emergencies in order to:
  - rescue personnel
  - protect major property
  - prevent/minimize environmental releases and exposure of general public
  - recover deceased victims
- Type of response to an emergency is left up to the official(s) in charge of the emergency situation

Emergency Dose Limits

- *10 rem (0.1 Sv) maximum*: Protecting major property where the lower dose limit of 5 rem (0.05 Sv) is not feasible
- *25 rem (0.25 Sv) maximum*: Lifesaving or protection of large populations where the lower dose limit is not practicable
- *Greater than 25 rem (0.25 Sv)*: Lifesaving or protection of large populations - only on a voluntary basis to personnel fully aware of risks involved

Example

Lesson 7 Quiz

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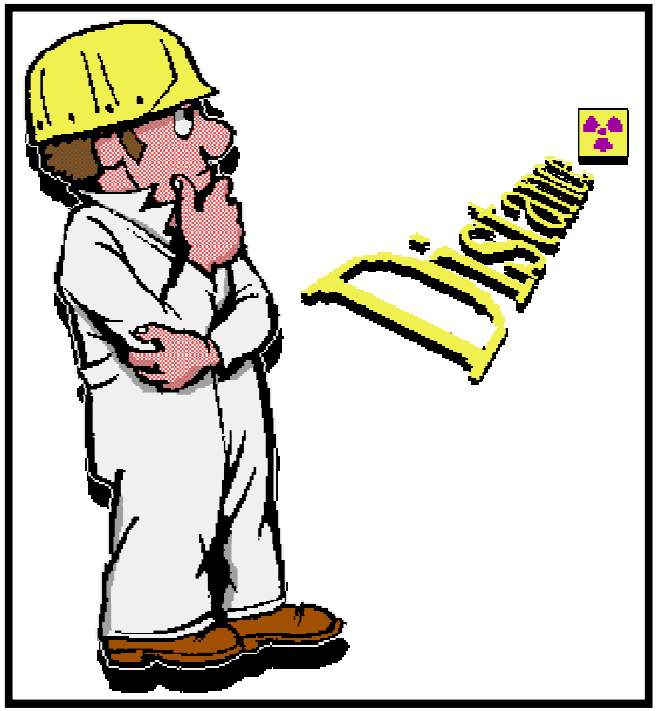
Break

Lesson 8
High Radiation Safety



- Areas with High Radiation Levels
- General Entry, Work and Exit Requirements
- Physical & Administrative Controls

Lesson 8
Enabling Objectives

Identify the requirements for entry into High Radiation Areas

1. IDENTIFY sources and locations that may produce High Radiation and Very High Radiation Areas.
2. DISCUSS the requirements for entering, working in, and exiting High Radiation and Very High Radiation Areas.
3. DISCUSS the physical and administrative controls for access to High Radiation and Very High Radiation Areas.

High Radiation Area

Any area, accessible to individuals, in which radiation levels could result in an individual receiving a deep dose equivalent in excess of 1 mSv (100 mrem) in 1 hr at 30 cm from the radiation source or from any surface that the radiation penetrates.

Notes:

- Caution or Danger may be used.
- 30 cm = 11.81 inches ~ 1 ft

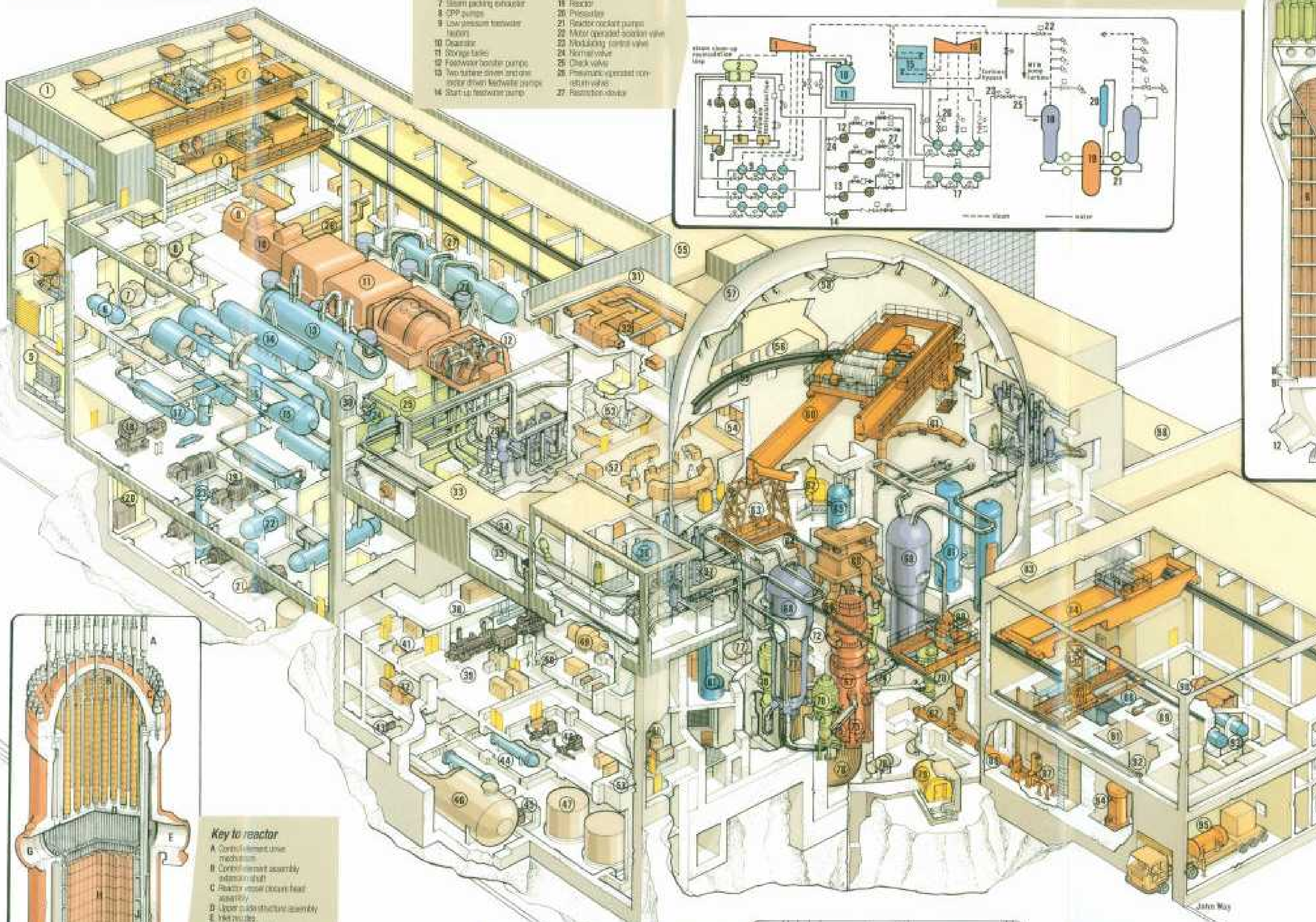
Very High Radiation Area

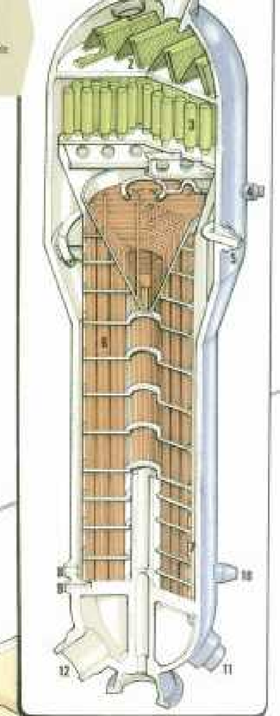
Any area, accessible to individuals, in which radiation levels could result in an individual receiving an absorbed dose in excess of 5 gray (500 Rad) in 1 hour at 1 meter from a radiation source, or from any surface that the radiation penetrates.

Utility : Korea Electric Power Corporation
NSSS system designer : Korea Atomic Energy Research Institute
NSSS/turbine supplier : Korea Heavy Industries & Construction Co. Ltd.
Architect engineer : Korea Power Engineering Company, Inc.

1 Low pressure turbine
2 Condenser
3 Hotwell
4 Condensate pumps
5 Condensate polishing
6 Steam jet air ejector
7 Steam packing exhauster
8 CPP pumps
9 Low pressure feedwater heaters
10 Deaerator
11 Storage tanks
12 Feedwater booster pumps
13 Two turbine driven and one motor driven feedwater pumps
14 Start up feedwater pump
15 Two stage moisture separator reheater
16 High pressure turbine
17 High pressure feedwater heaters
18 Steam generators
19 Reactor
20 Pressurizer
21 Reactor coolant pumps
22 Motor operated isolation valve
23 Modulating control valve
24 Normal valve
25 Check valve
26 Pneumatic operated non-return valves
27 Restriction device

1 Steam outlets
2 Dryers
3 Separators
4 Recirculation nozzle
5 Downcomer feedwater nozzle
6 Tubebundle
7 Economizer
8 Handhole
9 Blowdown nozzle
10 Economizer feedwater nozzle
11 Reactor coolant outlets
12 Reactor coolant inlet





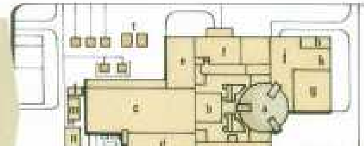
Key to reactor

A Control element drive mechanism
B Control element assembly extension shaft
C Reactor vessel closure head assembly
D Upper guide structure assembly
E Inlet nozzles
F Core support barrel
G Outlet nozzles
H Fuel assembly
J Core shroud
K Surveillance capsule
L Reactor vessel
M Incore instrumentation nozzles
N Lower support structure
O Core stop plug
P Flow skirt
Q Bottom head nozzle

John May

Site plan key

a Containment building
b Primary auxiliary building
c Turbine building
d Turbine building heater bay
e Access control building
f Secondary auxiliary building
g Fuel building
m Lubrication oil storage tank area
n Waste water pond
o Chemical storage tank area
p Fire pump and water treatment building
q Fresh water storage tanks



nuclear engineering international

This drawing was produced by the magazine Nuclear Engineering International, in collaboration with the Korea Atomic Energy Research Institute. It was published in the August 1992 issue

Entry Requirements

- Radiological Worker Training
- Pre-job briefing
- Specific radiological work planning document(s)
- Personal dosimeter and electronic self-reading dosimeters
- The area is monitored during access to determine the exposure rates to which individuals are exposed
- Physical controls are used where radiation levels exceed 1 rem in any hour at 30 centimeters

Work Requirements

Get the job done quickly and efficiently

- Know what to do and how
- Stay focused on the job
- Minimize small talk
- Leave the area ASAP

Minimize work dose

- Be aware of conditions
- Constantly apply ALARA
- Watch out for changing conditions
- Routinely check self-reading dosimetry

Exit Requirements

- Follow posted exit instructions (as applicable)
- Sign-out, including self-reading dosimetry readings

NOTE: No controls are established that would prevent rapid evacuation of personnel.

High Radiation Area Perspective

LHRA = Locked High Radiation Area
> 1000 mrem/hr @ 30 cm

RA
> 5 mrem/hr @ 30 cm

HRA
> 100 mrem/hr @ 30 cm

VHRA
> 500,000 mrad/hr @ 100 cm

Not drawn to scale

Physical Controls

- Control devices that prevent entry or causes radiation levels to drop upon entry (i.e., **switches**)
- An automatic control device that prevents use or operation of the radiation source or device while individuals are in the area (i.e., **interlocks**)
- A control device that energizes a conspicuous visible or audible alarm (i.e., **alarms**)
- Locked entryways with positive access control (i.e., **locks**)
- Continuous direct or electronic surveillance (i.e., **continuous surveillance**)

Administrative Controls

Administrative controls are typically used in combination with physical controls when physical controls alone are impractical. Administrative controls include:

- Radiological Work Control Documents
- ALARA Pre-Job Briefings
- In-Progress ALARA Inspections
- ALARA Post Job Reviews
- Radiological Postings
- Administrative Control Levels
- Special Radiological Training

Lesson 8 Quiz

+

Break

Lesson 9
Contamination Control

- Types and Sources of Contamination
- Contamination Control Methods
- Donning/Removing PC's
- Monitoring Equipment and Techniques
- Response to Contamination
- Types of Areas

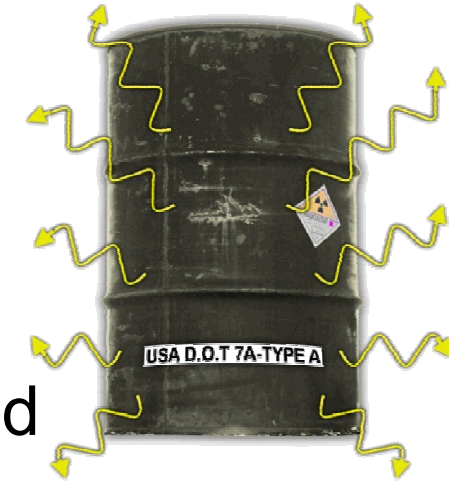
Lesson 9
Enabling Objectives

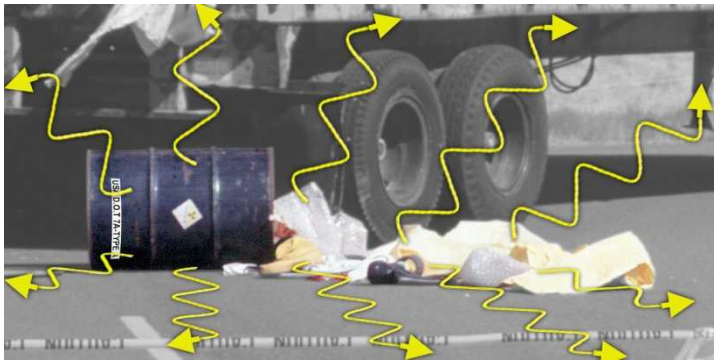
Understand contamination control methods

1. DEFINE fixed, removable, and airborne contamination.
2. RECOGNIZE sources and indicators of radioactive contamination.
3. IDENTIFY the normal methods used for decontamination.
4. DESCRIBE how contaminated areas are controlled to prevent the spread of contamination.
5. DEMONSTRATE the proper use of protective clothing.

Review: Radiation vs. Contamination

- Radiation is energy
- **Radioactive Material** - the physical material emitting the radiation
- **Radioactive Contamination** - radioactive material that is uncontained and in an unwanted place
- Exposure to radiation will *not* cause you to become contaminated





Types of Contamination

Fixed Contamination:

- Contamination that cannot be easily removed from surfaces.
- Cannot be removed by casual contact.
- May be released when the surface is disturbed (buffing, grinding, using volatile liquids for cleaning, etc.).
- Over time it may “weep,” leach, or otherwise become loose or removable.

Types of Contamination

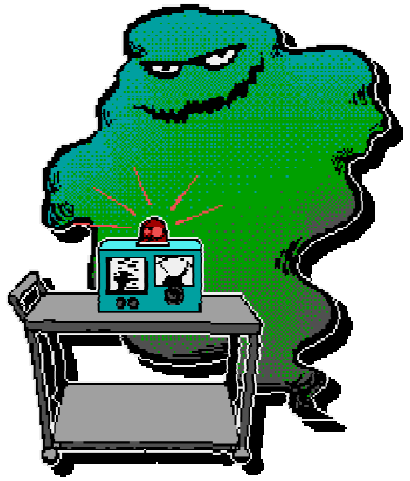
Removable Contamination:

- Contamination that can easily be removed from surfaces.
- Any object that comes in contact with it may become contaminated.
- It may be transferred by casual contact, wiping, brushing, or washing.
- Air movement may cause removable contamination to become airborne.

Types of Contamination

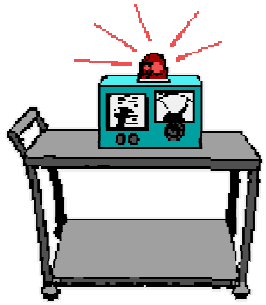
Airborne Contamination:

- Contamination suspended in air in the form of dusts, fumes, particulates, mists, vapors, or gases.
- Also referred to as airborne radioactivity and airborne radioactive material.



Sources of Contamination

- Leaks or breaks in radioactive systems, including air handling systems.
- Airborne contamination depositing on surfaces.
- Leaks or tears in radioactive material containers such as barrels, plastic bags, or boxes.
- Uncovering buried radioactive material.
- Breaches in sealed source encapsulations.



Sources of Contamination
Sloppy Work Practices

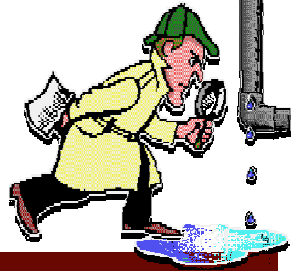
Sloppy work practices can lead to contamination of tools, equipment, and workers. For example:

- Opening radioactive systems without proper controls.
- Poor housekeeping in contaminated areas.
- Excessive motion or movement in areas of higher contamination.
- Improper usage of step-off pads and change areas.
- Violation of contamination control ropes and boundaries.

Sources of Contamination
Hot Particles

- Hot particles are small pieces of highly radioactive material that have escaped containment.
- Hot particles can be released when contaminated systems are opened or leak.
- Machining, cutting, or grinding on highly radioactive material can create hot particles.
- Seek additional training / guidance if your job will involve hot particles.
- Hot particles can cause a high, localized dose in a short period of time

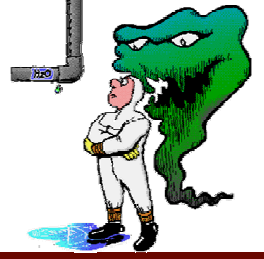
Indicators of Possible Contamination



- Leaks, spills, or standing water that is possibly from a radioactive system
- Damaged or leaking radioactive material containers
- Open radioactive systems with no observable controls
- Dust/dirt accumulations in radioactive contamination areas
- Torn or damaged tents and glove bags or containments on radioactive systems

Contamination Control Methods

- Prevention
- Engineering Controls
- Administrative Controls
- Personnel Protection Measures
- Decontamination



Prevention

- Identify and repair potential leaks before they become problems
- Establish adequate work controls before starting jobs and discuss controls during pre-job briefings
- Change gloves often to prevent cross-contamination
- Pre-stage areas to prevent contamination spread
- Comply with entry, exit, and equipment control procedures

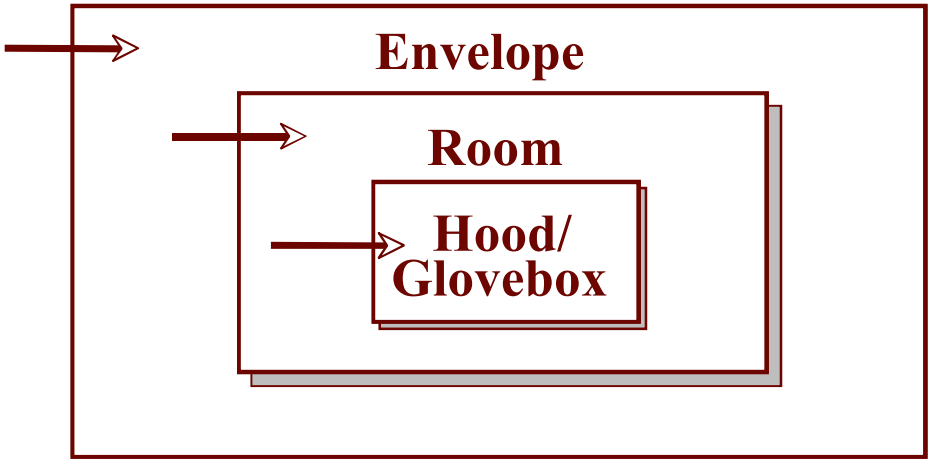
Prevention (Cont.)

Use good work practices

- Confine contamination to smallest area possible
- Minimize material, tools, etc., taken in and out of contaminated areas
- Watch for violations of contamination control procedures
- Do not violate ropes or barricades
- Do not pass items out of contamination areas without following procedures

Engineered Controls
- Facility Airflow -

Controlling airflow is a preferred method for controlling contaminants, including radioactive contamination.



- Airflow should be from areas of LEAST to MOST contamination.
- Air is typically exhausted through a monitored HEPA (High Efficiency Particulate Air) filtered system.

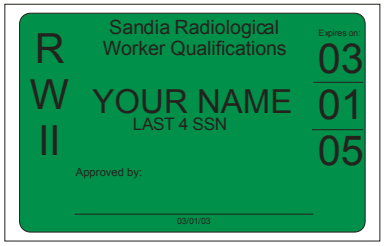
Administrative Controls

Limiting access time

Posting / labeling

TWDs/RWPs
Procedures
Work Plans

Briefings / meetings



Training / certifications

Personnel Protective Measures

If engineering controls are not adequate, then personnel protective measures will be used, such as protective clothing and respiratory protection.

Protective Clothing

- Required for entering areas where removable contamination and airborne radioactivity are present
- Prevents contamination of skin, hair, and personal clothing
- Referred to as PCs (protective clothing) or Anti-Cs (anti-contamination clothing)
- PPE (personal protective equipment) includes PC’s, safety glasses, hardhats, etc.

Protective Clothing - Basic Types

Supplied air with plastic suits

- Provides a high degree of protection
- Seldom needed - engineering comes first
- Slow to don, cumbersome, expensive

Coveralls / labcoats

- Usually the most appropriate
- Prevents skin contamination
- Disposable or reusable

Basis for PC Requirements

The type of protective clothing prescribed for entry into an area is based upon:

Contamination Levels:

- Multiple layers may be prescribed when removable contamination levels are 10 times the threshold values

Chemical And Physical Form Of The Contaminant:

- Wet work may require impermeable protective clothing / splash protection

Activities To Be Performed And Area Access

- Inspecting? Working? Walking? Climbing? Sitting? Crawling?

PC Examples

Various Components

- Anti-C coveralls
- Cotton liners***
- Surgical-type gloves
- Anti-C gloves
- Shoe covers
- Rubber or cloth overshoes
- Hood

***Cotton liners are for comfort only – not a layer of protection.

Proper Use of PCs

- Follow suggested procedures for donning and removing protective clothing.
- Minimize personal items under PC's like jewelry, pagers, ink pens, key rings, etc.

- Inspect prior to use. Replace damaged PC's.
- Protect your wrists by taping gloves to PC sleeves.
- Protect dosimeters from contamination. Place primary dosimeter under PC's and tape self reading dosimetry (in plastic bag) outside PC's.

Proper Use of PCs (Cont.)

- After donning, proceed directly from the dress-out area to the work area.
- Verify preparations are complete and requirements are met prior to entry.
- Keep your gloved hands and other potentially contaminated objects away from exposed skin.
- Change outer gloves as needed to prevent the spread of contamination.
- Immediately exit the work area and consult RP personnel if PPE integrity is compromised.
- Avoid getting PCs wet.

CAUTION!

Other area and activity hazards, such as heat, flame, hazardous chemicals, physical obstructions, electrical shock, and limited visibility, should be considered when prescribing protective clothing.

- Anti-Cs are usually made of flammable materials. EXTREME caution and special equipment and/or controls are needed when working with/near open flames, welding equipment, and heat sources!

LESSON LEARNED

February 13, 1997 - Oak Ridge Welder Fatality

- PC's were not fire resistant
- Fire watch was absent
- Welder's fire detection ability was impaired
- PPE was emphasized over engineering controls
- Individual died the next day

PC Donning & Removal

SUGGESTED INSTRUCTIONS FOR DONNING LEVEL I PROTECTIVE CLOTHING

1. INSPECT protective clothing prior to use for tears, holes, split seams or other defects that would diminish protection. REPLACE any damaged clothing.
2. DON personal dosimetry as appropriate.

   Note: TLD should be inside coveralls between the waist and neck on the front portion of the body.
3. DON surgeons gloves (and cloth glove liners – optional, for comfort only)
4. DON coveralls, taping coveralls over surgeons gloves.

   Note: If using coveralls with attached shoe covers and shoes are too big to fit in coveralls or coveralls are not long enough, the attached shoe covers may be removed and separate shoe covers donned, taping coverall legs to the shoe covers.
5. DON overshoes, if applicable.
6. DON outer gloves, pulling gloves over coverall sleeves.

   Note: Taping gloves to coveralls is dependent on situatio
   recommended.
7. DON respirator, if applicable.
8. DON hood, if applicable.

   Note: Taping respirator to hood is dependent on situation
   recommended.
9. DON self-reading dosimetry, if applicable.

   Note: Place self-reading dosimeter inside a bag and tape
   coveralls within three inches of, but not over, your person
10. Have a partner CHECK your clothing for proper donning
    entering the area.

SUGGESTED INSTRUCTIONS FOR REMOVING LEVEL I PROTECTIVE CLOTHING

1. REMOVE overshoes.
2. REMOVE exposed tape that will keep you from continuing to undress.
3. REMOVE outer gloves.
4. REMOVE remaining exposed tape that will keep you from continuing to undress.
5. REMOVE and invert hood, being careful not to contact your hair or face with gloved hands.
6. REMOVE respirator, if applicable.
7. TAKE DOWN barrier closure, if applicable.
8. PLACE self-reading dosimeter on step-off-pad (or other location provided).

   Note: Squeeze dosimeter out of the bag without touching it.
9. REMOVE coveralls.

   Note: Carefully push the coveralls down inside out, touching the inside only and
   ntacting clothing underneath.

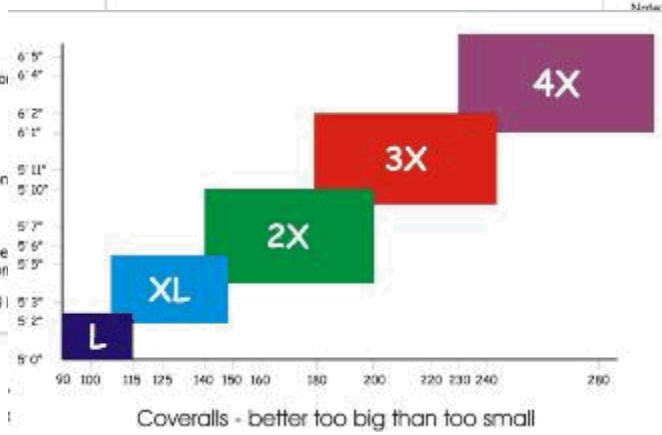
   OVE each foot from the shoe covers, stepping onto the step-off-pad as the
   s are removed.

   ACE barrier closure, if applicable.

   OVE inner gloves (and cloth liners, if applicable).

   UP self-reading dosimetry and proceed to the designated monitoring area.

   ORM required self-monitoring.



Coveralls - better too big than too small

Respiratory Protection

- Prevents inhalation of radioactive materials
- Radiological Worker training course DOES NOT qualify a worker to wear respiratory protection equipment.

Contamination Monitoring

- A search for radioactive contamination on equipment, personnel and in areas
- Direct and “swipe” techniques used
- Quantify and identify radioactive contamination
- Results used to determine posting and radiation protection requirements

Laboratory-based Instruments

Used to identify and quantify radioactive samples:

<< Low background sample counter

Gamma spectroscopy systems >>

Liquid scintillation >>

Air Sampling & Monitoring

Used in areas with potential for airborne contamination

Continuous Air Monitors (CAMs)

Fixed-head or portable air samplers

Response to Personnel Contamination

If contamination is detected:

- ✓ Remain in the immediate area

  Stay calm (probably not an “emergency”)

- ✓ Minimize cross contamination
  - – Move and touch as little as possible
  - – Put a glove on a contaminated hand
- ✓ Contact RP Personnel (RCT) for assistance

Response to Personnel Contamination (Cont.)

- Do not try to decontaminate clothing or skin yourself unless it is an emergency.
  - Wait for RCT to arrive

- Provide as much information as possible, to assist in identifying and controlling the source of contamination.

Decontamination

Decontamination is the removal of radioactive contamination from surfaces and locations.

- Accomplished by destructive and/or non-destructive means
- The radioactive material does not disappear, rather it is transferred to another surface or location

Decontamination (Cont.)

If contamination is detected, prompt decontamination is a valuable means of contamination control

Not always practical or possible

- Economical reasons
- Radiological conditions

Material Decontamination

The removal of radioactive material (i.e., contamination) from tools, equipment, floors, etc.

May be performed via non-destructive or destructive means:

- wiping
- cleaning
- scraping
- dissolving
- scabbling

Personnel Decontamination

- Notify RP personnel for assistance
- Perform limited, non-abrasive decon in conjunction with RP personnel when there is no injury

Injuries require first aid. Do not delay first aid for serious or life-threatening injuries due to presence of contamination.

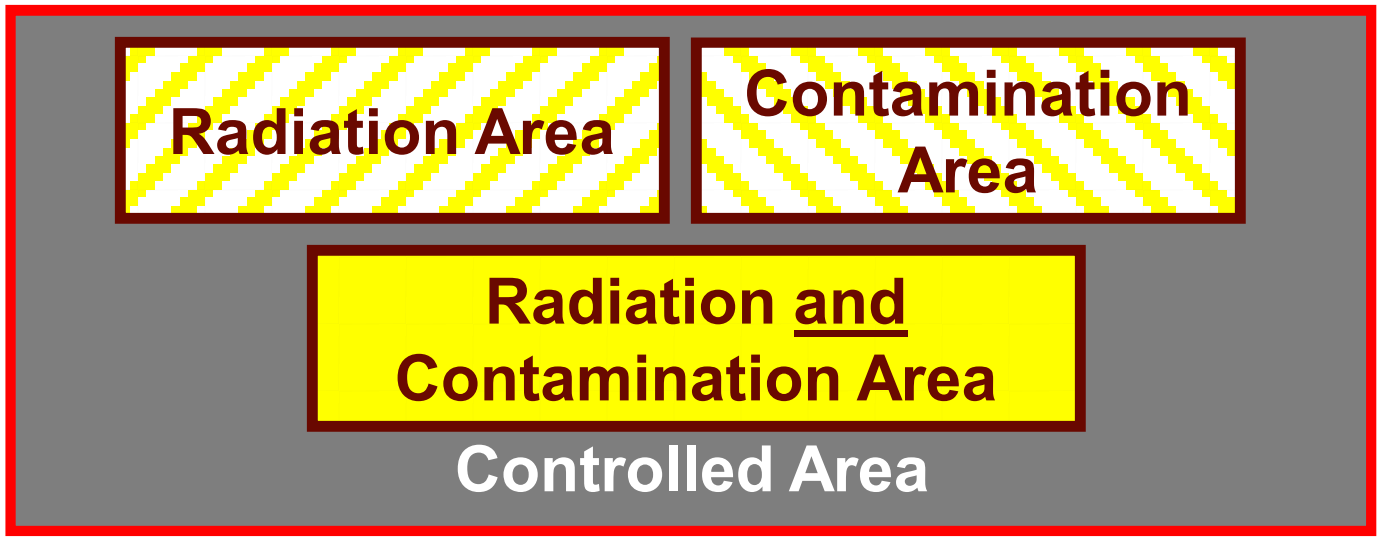
- Notify health services of skin contamination and decon efforts
- Complete appropriate health services form(s)

Personnel Decontamination (cont.)

- Mild soap and lukewarm water clean-up is the preferred method
- Organic solvents or harsh cleaners are not to be used
- Excessive scrubbing and abrasion can promote absorption of contaminants and damage the skin
- Decon beyond soap and water requires assistance from health services

REVIEW
Radiological Areas

Radiological Areas are contained within Controlled Areas and are based on existing or potential radiation and contamination levels



Contamination Area

Any area, accessible to individuals, where removable surface contamination levels exceed or are likely to exceed the removable surface contamination values specified in regulatory requirements, but do not exceed 100 times those values

High Contamination Area

Any area, accessible to individuals, where removable surface contamination levels exceed or are likely to exceed 100 times the removable surface contamination values specified in regulatory requirements.

Note: Caution or Danger may be used

Airborne Radioactivity Area

Any area, accessible to individuals, where the concentration of airborne radioactivity, above natural background, exceeds or is likely to exceed the derived air concentration values listed in regulatory requirements

Note: Caution or Danger may be used

Entry Requirements

- Radiological Worker Training
- Pre-job briefing and worker signature on pre-job briefing form
- Worker signature on approved radiological work planning document(s)
- Protective clothing and respiratory protection as prescribed
- Notify RP personnel of the presence of open wounds before entry

Work Requirements

- Avoid unnecessary contact with contaminated surfaces
- Secure lines, hoses, and cables to keep them from crossing in and out of the area
- Consider wrapping or sleeving materials
- Place contaminated materials in appropriate containers when job is completed
- Do not touch exposed skin
- Be aware of the presence of hot particles

Work Requirements (Cont.)

- Avoid stirring contamination because it could become airborne
- Limit the amount of material, tools, etc., taken into the area
- Do not eat, drink, smoke, chew, or apply cosmetics, or carry these items
- Wear PPE properly and as required
- Exit immediately if wounded or if PPE damage occurs, and contact RCT

Work Requirements (Cont.)

- Use lay-down areas to limit the spread of contamination
- Minimize the spread of radioactive spills and promptly notify RP Personnel
- Notify RP personnel of alarming or faulty contamination monitoring equipment

Exit Requirements

- Exit only at the step-off pad (unless there is an emergency)
- Remove protective clothing properly and carefully
- Observe radiological work planning document requirements and control point guidelines
- Have all items taken into the area surveyed for contamination (by RP Personnel) prior to removal

Exit Requirements (Cont.)

When exiting contamination areas, high contamination areas, and airborne radioactivity areas:

- Perform a whole-body frisk as soon as possible following exit from the area, but prior to washing, showering, or exiting controlled areas
- Frisk any personal items (papers, pens, jewelry, dosimeters, etc.) carried into the area.
- Do **NOT** remove tools or other material and equipment. Released only after survey by trained RP personnel.

Exit Requirements (Cont.)

If a frisk cannot be performed at the exit from a contamination area, high contamination area, or airborne radioactivity area due to high background radiation levels, do the following:

- Remove PC's at Step Off Pad (SOP)
- Proceed directly to the nearest frisking station
- Conduct a whole body frisk

Lesson 9 Quiz

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Break