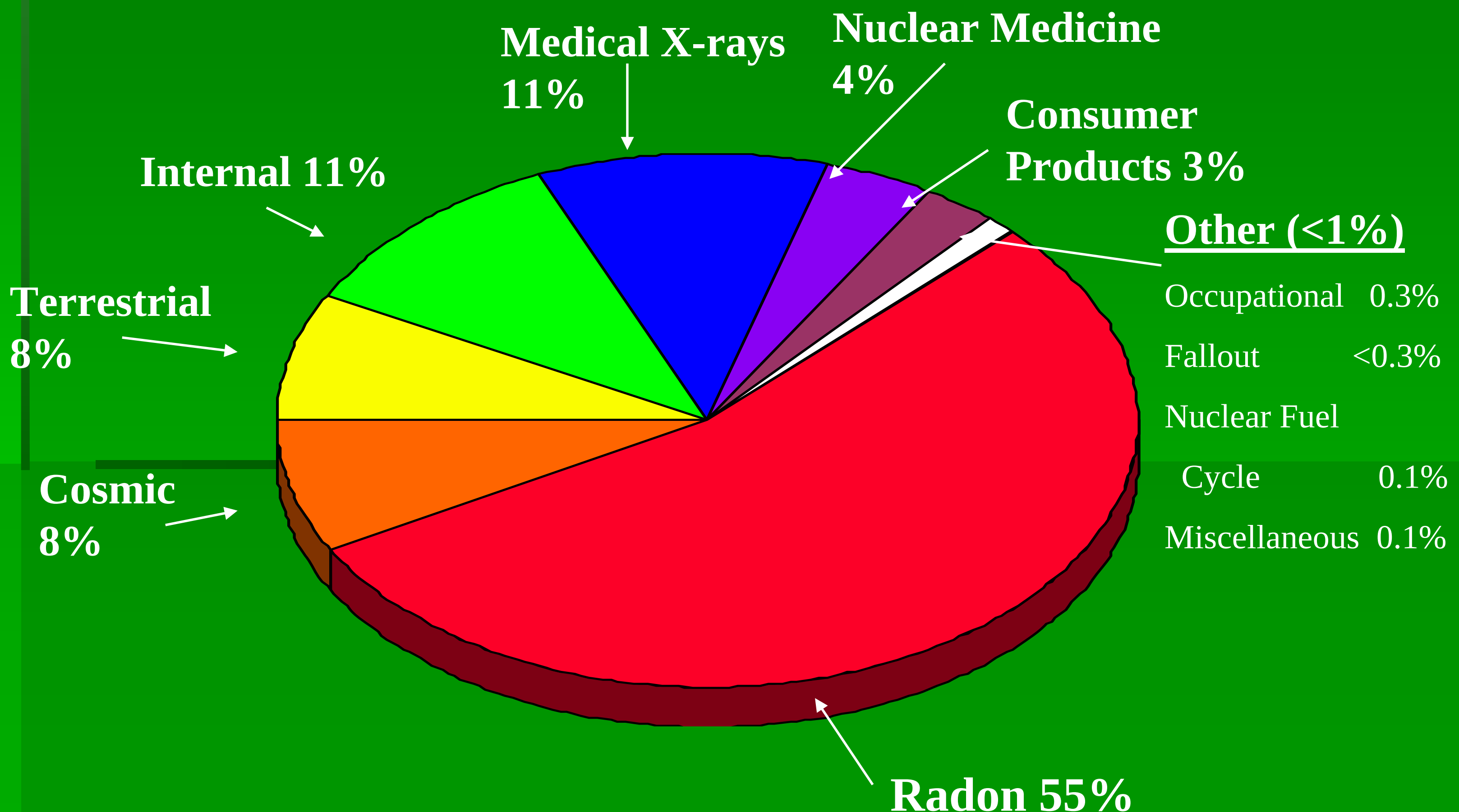
Radiation Safety Training for Veterinary Personnel

August 2007

Training Objectives

- Inform veterinary staff on the basic principles of radiation safety
- Discuss various types of radiation and the damage associated with exposures
- Examine hazards involved with radiation sources in veterinary medical practice
- Provide information on the safe handling of radiation sources

Sources of all Radiation



Occupational Radiation Sources
Radiation Producing Equipment

- **Diagnostic Radiology** - X-Rays
  - Computed Tomography (CT)
  - Radiographic Units (stationary & mobile)
  - Dental Units
- **Diagnostic Fluoroscopy** – includes catheterization labs, stationary & mobile C-arm fluoroscopy
- **Therapeutic Equipment**
  - Cobalt-60 Teletherapy Units - gamma rays
  - Linear Accelerators (Linac) - X-Rays

Occupational Radiation Sources from Radioactive Materials

- **Unsealed Sources** include:
  - Diagnostic Radiopharmaceuticals used for Nuclear Medicine procedures
  - Radioisotope Therapy Sources used in Thyroid Ablation procedures (Iodine 131)
  - Radioimmunoassay (RIA) Tests for research and testing purposes
  - Radioisotope Generators for Nuclear Medicine studies (Technetium-99m and Indium-113m)
- **Sealed Sources** include:
  - Brachytherapy: usually implantation or delivery of a dose via High Dose After-loading equipment (Iridium192, Cesium137, Iodine125, Strontium 90)
  - Instrument Sources (Barium 133, Cobalt 57, Cesium 137)

Radiation Sources in the Veterinary Practice

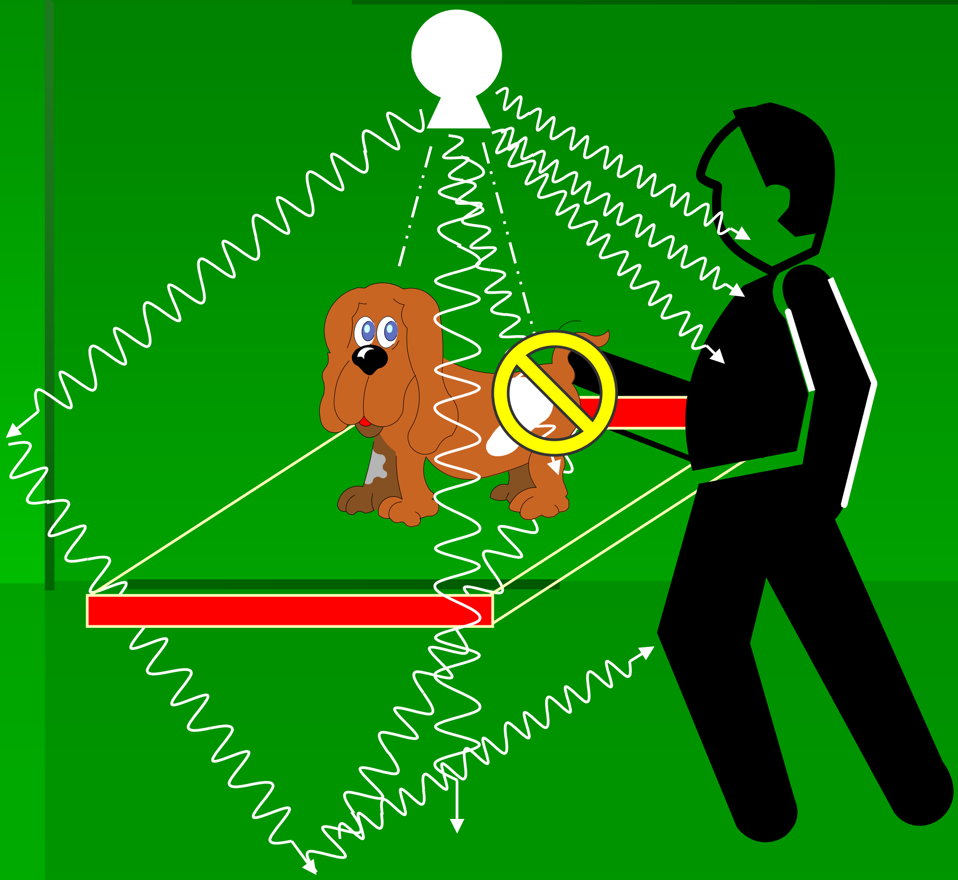
- Radiology
  - X-Ray machines
  - Nuclear Medicine
- Radiation Therapy
  - Cobalt Teletherapy
  - LinAc
  - Brachytherapy




Animals Injected with Radioisotopes

When an animal is injected with a radioisotope for a nuclear medicine study, the animal becomes a source of radioactivity and exposure. This includes all waste produced by the animal. The animal must not be handled without the proper dosimetry and must not be released without the approval of the nuclear medicine technician or radiation safety representative. All animals must meet pre-determined release criteria and meet ALARA requirements.

Source of X-Ray Exposure Animal Holding



Not all x-rays are attenuated by the patient. A percentage is scattered off of the patient and serves as a direct source of occupational exposure to the technician. The use of mechanical or physical restraints and sedation procedures should be used when possible, minimize radiation exposure to the worker. Holding should only be used once other methods are exhausted or the diagnostic quality is greatly impacted.

ALARA

- **A** As
- **L** Low
- **A** As
- **R** Reasonably
- **A** Achievable

- Radiation doses are kept as low as possible
- A regulatory requirement to minimize an individual's radiation exposure to the lowest level that can reasonably be achieved.
- ALARA program is required by Federal and State regulations

Methods to Achieve ALARA

- **Time**

  Decrease the time around a radiation source to decrease exposure

- **Distance**

  Increase distance from a radiation source to decrease exposure

- **Shielding**

  Increase thickness of proper shielding to decrease exposure

- **Contamination Control**

  Use disposable gloves, lab coats, safety glasses, etc. to decrease Exposure

Types of Radiation & Shielding

4 mil paper or 2 inches air will stop alpha particles with energy up to 6 MeV

Alpha Particles
up to 6 MeV

½ inch Lucite (Plexiglass) will shield beta

2 inches of lead reduces incident intensity 90%

Beta Particles
up to 2 MeV

X-rays and Gamma Rays
up to 2 MeV

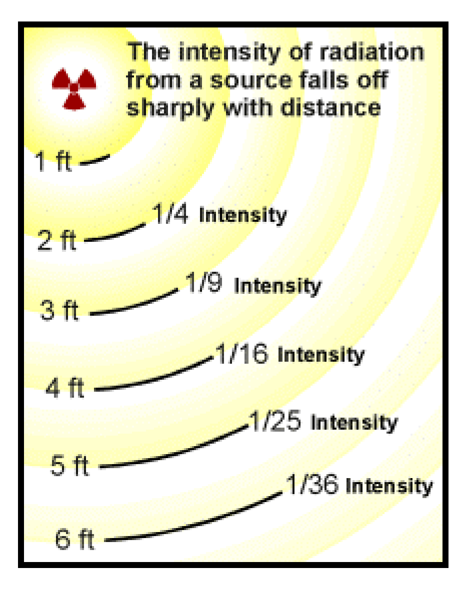
Neutron shielding may be of concern in Linear Accelerator use for machines operating over 10 MeV.

Inverse Square Law

- Exposure rate is proportional to the inverse square of the distance away from a point source:

$$\textbf{Exposure rate } \alpha \ \frac{1}{d^2}$$

- Doubling your distance from the source reduces the exposure rate by a factor of 4



Radiation Units and Terms

To effectively minimize exposure and understand the fundamentals of radiation, a working knowledge of radiation-related terminology and units is necessary.

Activity	Half-Life
Exposure	Exposure Rate
Absorbed Dose	Dose Equivalent

Activity

Activity is the quantity of radioactive material present. This is defined in terms of the number of disintegrations of radioactive atoms per unit time.

The **Curie** (Ci) is the standard unit used to express activity

1 Ci = 3.7×10^{10} disintegrations per second

1 millicurie = 3.7×10^{7} disintegrations per second

The **Becquerel** (Bq) is the SI unit used to express activity

1 Bq = 1 disintegration per second = 3.7×10^{-10} Ci

37 MBq = 1 millicurie

Half-Life

The **half-life** is defined as the amount of time it takes for a radioactive isotope to be reduced to ½ of its initial activity. Each radioisotope has its own half-life value.

Example:	Technetium - 99m	$t_{1/2}$ = 6.02 hours
	Phosphorus – 32	$t_{1/2}$ = 14.3 days
	Cesium –137	$t_{1/2}$ = 30 years

For any radioisotope, the following example would be true:

Starting activity	# of half-lives elapsed	Remaining activity
100 millicuries	0	100 millicuries
100 millicuries	1	50 millicuries
100 millicuries	2	25 millicuries
100 millicuries	3	12.5 millicuries

Exposure & Exposure Rate

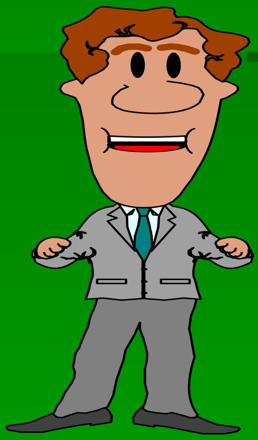
Exposure measures the total amount of ionization produced by gamma rays and x-rays absorbed in air. These radiations can remove electrons from atoms to create ions.

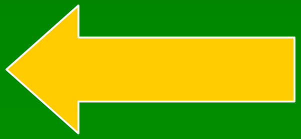
- Unit for exposure is Roentgen (R)
- 1 R produces ~ 2 billion ion pairs per cm^3 air

Exposure Rate is the amount of radiation exposure per unit time

- Exposure rate can be expressed as R/hr or mR/hr

Exposure vs Contamination



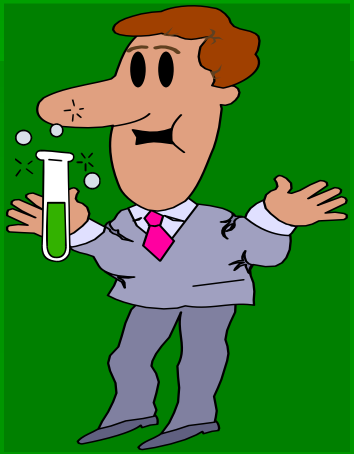


Exposure is an encounter with a radiation field.

Radiation energy may be absorbed by the person's cells

(Exposure <u>does not</u> make you radioactive)

Contamination is the physical presence of particulate radioactive matter <u>on</u> or <u>inside</u> an object, animal or person.



(Contamination can cause Exposure)

Absorbed Dose

Absorbed dose is the amount of energy absorbed per unit mass. It is an improvement on the roentgen unit because it can be used for all types of ionizing radiation.

The standard unit is **rad**

1 rad = 100 ergs/gram = 62.5 x 10^6 MeV/g

(where 1 erg is approximately the amount of energy required for a housefly to do a pushup!)

The SI Unit is **Gray (Gy)** or 1 Joule/ kilogram

1 Gy = 100 rad

Dose Equivalent

Dose Equivalent (rem) is a measure of the biological damage due to a radiation dose absorbed by living cells. This is equal to the absorbed dose in **rad** multiplied by a weighting factor (**W_R= 1** for gammas and X-rays). The **rem** is the legal unit used for a radiation worker's occupational radiation dose records.

Standard Unit = **rem (r**oentgen **e**quivalent **m**an**)**

1 rad = 1 rem (for gammas and X-rays)

SI Unit = **Sievert** (Sv)

1 Sv = 100 Rem

Absorption of Radiation Energy

↓

Ionization or **Excitation** of Molecules

↓

Formation of a **Sub-Lesion**

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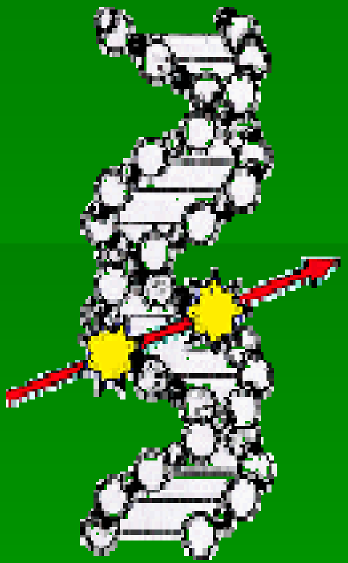
Cellular Repair or **Development of Lesions**



Chromosome damage

Latent, Low Dose Effects can cause:

Gene Mutations

Cancer ?

In-Utero Effects

Acute, High Dose Effects can cause:

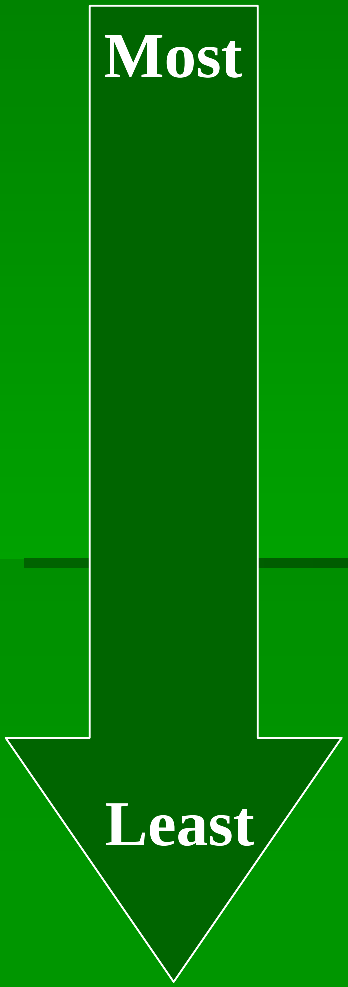
Cell Death

Tissue Damage

Whole Body Effects

Relative Radiosensitivity

the relative susceptibility of cells, tissues, organs or organisms to the harmful effect of ionizing radiation, as described by the Law of Bergonie and Tribondeau, in 1906.



Lymphocytes

Immature Red Cells in Bone Marrow

Gastrointestinal Tract Cell Lining

Gonads

Skin (Proliferating Layers)

Vessels and Cavity Linings

Organs and Glands

Connective Tissues

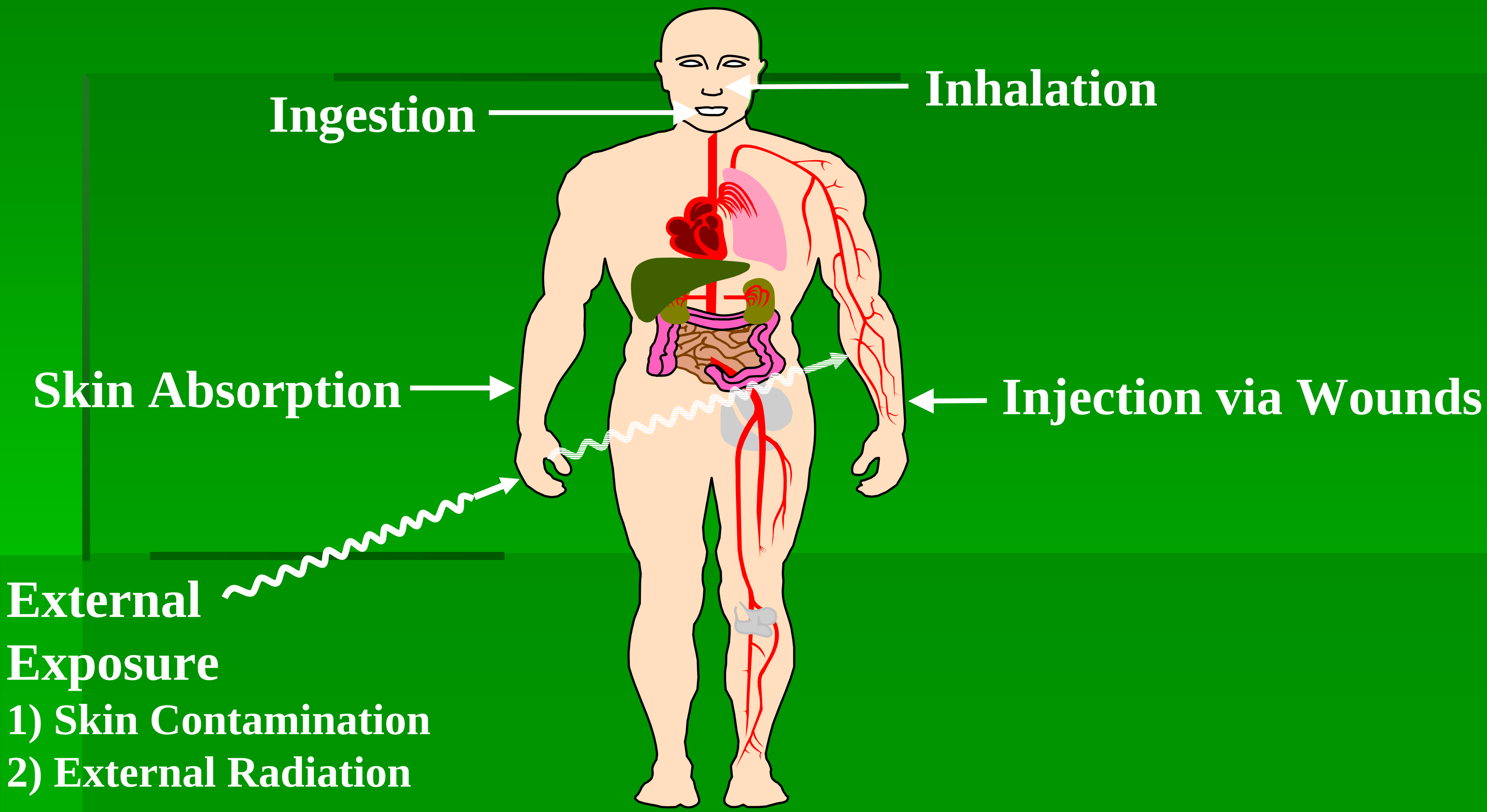
Muscles

Nerves

Fat

Exposure Pathways

Internal and External Radiation Doses

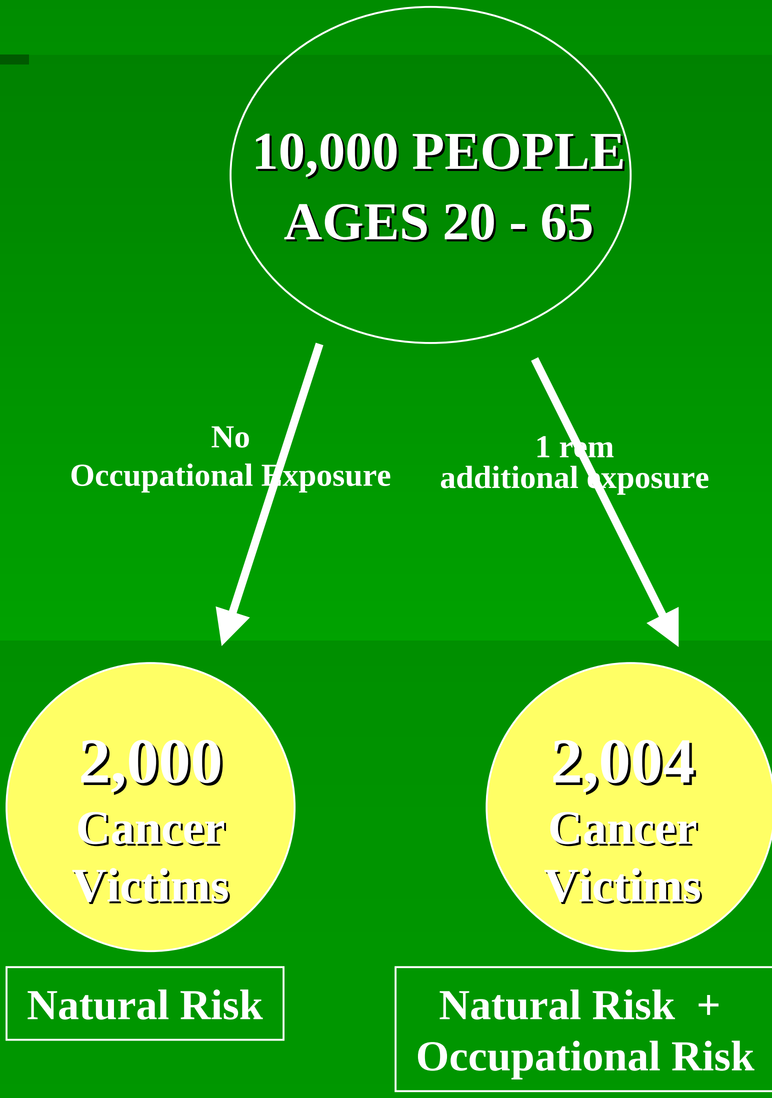


Life-time Cancer Risk

No one knows exactly what the chances are of getting cancer from a *low-level radiation dose*. This is because the few cancers which may occur *cannot be distinguished from cancers due to other causes*. However, estimates can be made by extrapolating from scientific data on radiation effects observed at high dose levels. Information is available from experimental animal research, lung cancer incidence in uranium miners, the survivors of the Hiroshima and Nagasaki bombings, the famous case of the radium watch dial painters and others.

In a group of 10,000 people who receive no occupational radiation dose, ~ 2,000 of those people will develop some type of cancer during their lifetime ! This is a 20 % risk of developing cancer from natural causes(*inherited effects, pollutants, smoking, alcohol, drugs, natural background radiation, etc*.).

If this same group of 10,000 people are exposed to a whole body dose of 1 rem, it is projected that an additional 4 cancers will arise in this population to give a total of ~ 2,004 cancers. These additional 4 cancers in 10,000 people amount to a 0.04 % risk.Thus, the natural risk of cancer is apparently *very much greater* than that incurred by receiving a 1 rem whole body occupational radiation dose.



Permissible Dose Limits

Occupational Limits for Adults are governed by 10 CFR 19 and 20, as well as 15A NCAC 11.1604; ALARA practices should be implemented to minimize occupational exposure

Whole Body	5,000 mrem / yr
Eye lens	5,000 mrem / yr
Extremities or Skin	50,000 mrem / yr
Pregnancy (Declared)	500 mrem / 9 mon
General Public	100 mrem / yr
Uncontrolled Dose Rate	2 mrem in any 1 hour

External Personnel Monitoring

Whole Body Dosimeters

- Detects beta, gamma and X-ray
- Measures radiation dose to the torso
- Worn between the waist and collar
- Exchanged on a monthly, quarterly, semi-annual basis

Picture courtesy of Landauer, Inc.

External Personnel Monitoring
Film Badges

Picture courtesy of ICN and NDT Resource Center

- Personnel dosimetry film badges are commonly used to measure and record radiation exposure due to gamma rays, X-rays and beta particles. The detector is, as the name implies, a piece of radiation sensitive film. The film is packaged in a light proof, vapor proof envelope preventing light, moisture or chemical vapors from affecting the film.

External Personnel Monitoring

Ring Badges

Picture courtesy of Landauer, Inc.

- Issued to radiation workers who may be exposed to significant hand dose

- Wear on **appropriate** hand and **digit (**i.e., the one **closest** to the radiation source). The ring label should be **toward** the source and worn **under** a latex glove when using unsealed sources.
- Rings are replaced **monthly** or **quarterly**

* As a rule of thumb: Minimum Detectable Dose is 30 millirem or X-rays or gamma rays and 40 millirem for high energy beta radiation

Dosimeter Recommendations

- Wear it when near a radiation source
- Wear it properly on the body
- Do not wear someone else's badge
- Store away from radiation sources
- Store in a room temperature, dry location (do not expose to extreme heat or allow to get wet)

Internal Personnel Monitoring

Thyroid and Urine Bioassays

- Used to detect internal contamination after working with unsealed sources of radiation
- Measures radiation dose to the thyroid or whole body via excretion of materials via urine
- Requires counting instrumentation to perform and complete testing (portable survey meter for thyroid counting and Liquid Scintillation Counter/Gamma Counter for urine sampling)

Personnel Safety Practices

For Diagnostic Radiology & Fluoroscopy Services, sound ALARA practices should include:

- Monitoring all persons with appropriate dosimetry if they work with X-ray units or are present in a restricted area
- Wearing of lead aprons by operators and imaging staff present in the imaging suite
- Declared pregnant workers should not hold patients during radiology procedure
- Instruments should be available to assess the adequacy of shielding in the room barriers (walls, floors, windows, ceilings)
- Use mechanical restraints or sedation techniques in lieu of staff holding patients

Personnel Safety Practices

- Maximize your shielding: Lead aprons of at least 0.25mm lead equivalent; when not assisting with a procedure, stand outside the room or behind a leaded barrier
- Dosimetry monitoring should be worn outside the lead apron/thyroid shield
- Minimize time of procedure and the number of repeat exposures
- Increase distance between you and the radiation source and patient

Personnel Safety Practices

Nuclear Medicine - Radioisotopes

- Monitor <u>all persons</u> with appropriate dosimetry if they work with radioisotopes or are present in a restricted area
- Whole body and ring dosimeters are used by nuclear medicine technicians and staff handling sources
- Declared pregnant workers should be monitored for internal and external exposures
- Survey instruments should be available to check contamination in all preparation and patient areas

Common Isotopes Used in Nuclear Medicine Studies

- Technetium-99m $t_{1/2}$ = 6.02 hours
- Iodine-131 $t_{1/2}$ = 8.04 days
- Iodine-125* $t_{1/2}$ = 60 days

*Isotope Used for Thyroid Ablation Treatment

Personnel Safety Practices

Radioisotope Therapy – Unsealed Sources

- Monitor all persons with appropriate dosimetry if they work with radioisotopes or are present in a restricted area
- Whole body and ring dosimeters are used by nuclear medicine techs and staff handling sources/patients
- Declared pregnant workers should be monitored for internal and external exposures
- Contamination control measures should be used by staff handling preparations and patients
- Bioassays should be used for personnel handling radioisotopes (e.g., I-131)

Personnel Safety Practices

Sealed Source Radiation Therapy - Brachytherapy

- Monitor all persons with appropriate dosimetry if they work with the sources or are present in a restricted area
- Whole body and ring dosimeters are used by staff manipulating these sources (not with bare hands)
- Declared pregnant workers should not be exposed to brachytherapy sources, if possible
- Techniques for reducing handling times should be practiced by staff required to use these sources
- Portable survey instruments should be available to assess the exposure rates in the area and monitor for lost/dislodged sources

Exposure Monitoring for Declared Pregnant Worker

A Prenatal Exposure Policy is an integral component in every ALARA program

- 500 millirem dose limit to embryo/fetus during the entire gestation period (15A NCAC 11.1610)
- Declaration must be made in writing to the licensee employing the worker. Declaration is a voluntary decision for the radiation worker
- Monthly dosimetry and urinalysis may be required
- Copies of dosimetry results should be directed to the declared pregnant worker

Procedures for Nuclear Medicine Patients

- Proper Protective Apparel for Workers
  - Lab coat
  - Gloves
  - Shoe covers
- Cages posted with “Caution Radioactive Materials” sign while in treatment
- NO handling of animals unless medically necessary
- Cages must not be cleaned until released by Nuclear Medicine staff or radiation safety personnel

Emergency Procedures

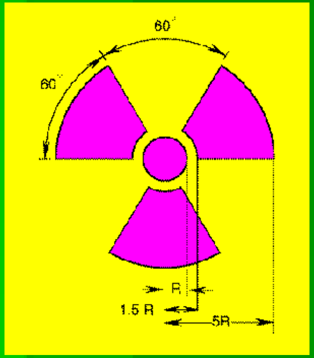
- Worker Contamination with Radioisotopes
  - Use warm water and mild soap for removal
  - Perform personnel contamination surveys
  - Perform bioassays for internal contamination and seek medical treatment
- Worker Over-exposure to X or Gamma rays
  - Seek immediate medical evaluation; report to proper regulatory agencies if overexposure occurs
- Worker Injury and Radioactive Contamination
  - Provide immediate medical aid for serious injuries
  - Decontaminate a worker after medical aid is given
- Dosimetry Evaluation
  - Expedite evaluation of personnel dosimetry

Security Requirements for Radiation work

- Licensees and registrants are required to establish security measures that prevent theft or diversion of materials, in addition to preventing unnecessary exposure.
- Select radioactive materials used in veterinary practices may be subject to Increased Security Controls (select isotopes and quantities found in Teletherapy units, irradiators).

Radiation posting requirements

- Areas where radioactive materials or radiation producing devices are used must be appropriately posted to warn others of the potential hazards in the area
- Postings should be conspicuous, bear the radiation symbol (trefoil) and the appropriate words for the intended warning:



Caution- Radioactive materials
Caution- Caution Radiation Area
Caution- High Radiation Area
Caution- Radiation Producing Devices

References

- 15A NCAC 11 – Regulations for the Protection Against Radiation
- 10 CFR 19 and 20
- Nuclear Regulatory Commission Regulatory Guide 8.29
- National Council for Radiation Protection (NCRP) Guides
- Wikipedia, World-wide web
- NC Radiation Protection Section Webpage: http://www.ncradiation.net
- North Carolina State University, Radiation Safety Division