Lesson 13a. Radiation Hazards & Safety

April 21, 2005
Stan Addison
University of Washington
Dept. of Environmental Health & Safety

Radiation In Our Environment

Radiation has been in our environment since the beginning of time. All plants and animals are continuously bombarded by NATURAL BACKGROUND radiation. Man-made radiation was discovered in 1895.
Radiation means matter or energy moving outward from a point of origin.

Ionizing radiations are generated by interactions occurring within the atom.

Ionizing Radiation has enough energy to remove electrons from atoms.

Atoms emit ionizing radiation to reduce excess energy and attempt to achieve stability.

Some naturally occurring atoms do this spontaneously, other atoms are forced into instability by man-made processes.
**Materials vs. Machines**

Radioactive Materials
- Naturally occurring or made (reactors, accelerators, nuclear weapons)
- Produce radiation at all times, but decays away over time.
- Often loose material and can be spread around

Radiation Machines
- X-ray machines, cyclotrons, accelerators, etc.
- Most produce x-rays, but high energy machines may produce other radiations.
- Only produce radiation when turned on.
- A by-product of high energy machines can be radioactive materials.

**Five basic types of ionizing radiation**

- X-ray results from electron energy changes
- X-ray and gamma are identical except for origin
- Alpha, neutron, beta, and gamma come from the nucleus
Gamma rays and x-rays are forms of energy, similar to visible light and radio, but much more energetic.

Penetrating Energy

Radiation Intensity Changes with Distance

Follows the “inverse square” \((1/r^2)\) relationship

For example; doubling your distance cuts exposure to 1/4, and tripling distance cuts exposure to 1/9.
Radioactive Decay
(Materials)

After Time

Pure Sample
Full Activity

Decayed
Sample
Lower Activity

Radioactive Decay
(Materials)

100%
75%
50%
25%
0%

HALFLIFE

1
2
3

Materials and Machines

Materials Only

May come from inhalation, ingestion, injection, absorption, or injury

Collision

Materials Only

Could be partial or whole body.

Often concentrates in particular organs.

Radiation Hazards
(External vs. Internal)


**Early Radiation Injury**

Radiation injury to the skin as a byproduct during an X-ray examination.

**Fate of Early Radiologists**

The early radiologists often suffered severe radiation-related health issues.

**Radiologist Fingers**

The fingers of a radiologist showing severe radiation damage.
Human Use of Radiation

The availability and use of radioactive materials “exploded” after World War II.

Natural Background Radiation

- About 3 mSv (300 mrem) per year

Radiation Dose Equivalent

- Dose Equivalent - Unit to express the amount of radiation energy absorbed in matter, adjusted for biological damaging ability.
- sievert (SI unit - Sv), or rem (traditional unit)
- millisievert or millirem is 1000 times smaller
- 1 Sv = 100 rem
- 1 mSv = 100 mrem
Annual Radiation Dose Limits

- Occupational
  - 0.05 Sv (5 rem or 5000 mrem) whole body
  - Individual organs, skin and extremities (50 rem)
  - Exception: Lens of eye = 0.15 Sv (15 rem)
- Embryo/Fetus (of radiation worker)
  - 5 mSv (0.5 rem)
- General Public
  - 1 mSv (0.1 rem)

Radiation Health Effects

- High-level radiation effects are acute effects which are manifested shortly after (hours, days, weeks) a large exposure (1 Sv or 100 rem+).
- Low-level radiation effects are described as either latent effects, appearing many years after a “non-lethal” acute dose, or as chronic effects after many years of small doses (like radiation workers).

Acute/High Level Radiation Effects in Humans

- Radiation Burns (over 2 Sv or 200 rem) - local or whole body
- Cataracts (over 1.5 Sv or 150 rem)
- Whole Body Bone Marrow Injury (over 1 Sv or 100 rem) - may cause death if injury is severe.
- GI Tract Injury (over 6 Sv or 600 rem) - causes death in days or weeks.
- Central Nervous System Injury (over 50 Sv or 5000 rem) - causes death in hours or days.
- Other?
Low Level Radiation Health Effects

- Genetic mutations - probably takes 1 Sv (100 rem) to double mutation rate in man.
- Abnormalities induced in an exposed fetus - about 4% chance of occurrence per 0.1 Sv (10 rem)
- Cancer in the exposed individual - 0.1 Sv (10 rem) given to 100 people in U.S. population would be expected to cause about 1 extra cancer over a lifetime. About 42 of these people would be expected to get cancer from natural causes.

Radiation Protection puts many scientific principles and techniques into practice.

Substitution

- Fossil fuel plants can replace nuclear power plants.
- Magnetic Resonance Imaging can replace x-ray imaging in a few situations.
- Fluorescent markers can replace radionuclides in some lab tests.
- Downside - Cost, other hazards?
Treatment?

- Success is poor. Attempts to "irradiate" radioactive materials and turn them into different radioisotopes with shorter half-life nearly always fail.
- If someone suggests that you invest in a radioisotope treatment scheme - save your money!

Isolation (Burial)

- Radioactive materials have historically been put into isolation and burial sites - with arguable success.

Shielding

- Shielding stops alpha and beta particles and greatly reduces x-ray and gamma radiation.
  - Distance reduces exposure by 1/r^2 for x-ray and gamma radiation
  - Distance in air stops alpha and beta particles.
  - Reducing the amount of time around a radiation source directly reduces radiation exposure.
Methods to Reduce Internal Intake

- Containment and/or exhaust (fume hoods in labs).
- Contamination surveys.
- Good hygiene - washing hands, contaminated skin, and contaminated articles.
- Good personal habits - no hand to face/mouth contact, no eating/drinking, no application of cosmetics.

Methods to Reduce Internal Intake

- Use of protective clothing and personal protective equipment.
- General Protective Measures:
  - Knowledge of hazards.
  - Area Control: signage, records, and security.
  - Appropriate facilities and equipment for use and control of radioactive materials.

Encountering Radiation in the Workplace


**Encountering Radiation in the Workplace (Continued)**

- Measurement and Quality Control
- Static Control

**Man-Made Radiation in the Environment**

- Biomedical/Industrial wastes or byproducts
- Lost sources

**Man-Made Radiation in the Environment**

- Active Production or Processing Sites
- Closed/Abandoned Production or Processing Sites
Dirty Bombs (Radiological Dispersal Devices)?

June 2005: US Senate surveys government officials and other US and international experts. Ordinary explosives pared with radioactive material seen as the likeliest "Weapon of Mass Destruction".

Backscatter Security X-ray

TSA expects to begin using the controversial backscatter x-ray later this year to show airport screeners a clear picture of what's under a passenger's clothes.

-- USA TODAY, May 15, 2005

Airport Baggage Scanning Equipment

New Airport explosive detection systems are being used in US and many non-US airports to x-ray scan checked baggage. The new equipment uses much higher levels of radiation than equipment used to inspect carry-on baggage (which will not noticeably damage most films).

Example:

Non-x-rayed film

Radiation damaged film
Overview

What we’ll be covering today:
- Noise, hearing and hearing loss
- Occupational noise
  - How to measure it
  - How much is too much?
- Hearing loss prevention
  - Controls
  - Hearing protectors
- Non-occupational noise
- Community noise

Noise

Definition = Unwanted sound (vibrations in air)
Measured by: sound pressure (loudness)
  - decibels (dB)
And: frequency (pitch)
  - hertz (Hz) - vibrations per second

How We Hear

Anatomy of the Ear
Loudness

- Human ear: extremely large range of sound pressure sensitivity
- Convenient to convert linear scale (sound pressure, $P_s$) to log scale (sound pressure level, dB)

Noise Levels

Noise Levels of some familiar sounds

<table>
<thead>
<tr>
<th>Relative Response (dB)</th>
<th>Frequency (Hz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>10</td>
</tr>
<tr>
<td>5</td>
<td>100</td>
</tr>
<tr>
<td>10</td>
<td>1000</td>
</tr>
<tr>
<td>15</td>
<td>10,000</td>
</tr>
</tbody>
</table>

Sensitivity of human ear

Frequency is Important, too ...

- Sensitivity of human ear and frequency relationship
**Lesson 13: Radiation & Noise**

**ENV H 311: Intro. to Environmental Health**

---

**Hearing Loss**

![Diagram of the ear showing hearing loss]

---

**Types of Hearing Damage**

- **Conductive** (outer or middle ear)
  - Sometimes reversible
  - Acoustic trauma, accident, etc

- **Sensorineural** (inner ear)
  - Damage to nerves; irreversible
  - Includes NIHL, presbycusis

---

**Inside the Cochlea...**

- **Before noise:**
  - Inner and outer hair cells neatly arranged

- **After noise:**
  - Hair cells in disarray, or even missing
Types of Hearing Damage

- Also:
  - Temporary Threshold Shift
  - Permanent Threshold Shift
  - Tinnitus
    (more on this later)

How is Hearing Tested?

- Sound-treated booth
- Tympanometry
- Standard audiometry
  - Pure tone air conduction
  - Pure tone bone conduction
  - 5 dB steps
- Other (newer) tests available, as well

Age-related Hearing Loss

Even by age 60, the average person doesn't have hearing impairment from age alone
**Effects of NIHL**

- NIHL affects high frequency hearing first.
- NIHL makes it harder to communicate:
  - On the job
  - In situations with background noise (jobsite, restaurant)

**Other Effects of Noise**

- Dilation on the pupil
- Secretion of thyroid hormone
- Heart palpitations
- Secretion of adrenalin
- Secretion of adrenalin cortex hormone
- Movement of the stomach and intestines
- Muscle reaction
- Constriction of blood vessels
Lesson 13: Radiation & Noise

Ways to Measure Noise

- **Sound Level Meter**
  - Area/personal measurements, point-in-time levels
  - Cheap, easy, good for continuous noise, immediate HPD needs

- **Dosimeter**
  - Area/personal measurements
  - Point-in-time or average levels, continuous or variable noise
  - Expensive, but low labor

Noise Standards

OSHA vs. NIOSH

Assumes worker using no hearing protection

Top 10 SICs by % workers >85 dBA

<table>
<thead>
<tr>
<th>Economic Sector</th>
<th>Total no. production workers</th>
<th>No. noise-exposed</th>
<th>% noise-exposed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tobacco products</td>
<td>306,399</td>
<td>57,764</td>
<td>54.3</td>
</tr>
<tr>
<td>Primary metals</td>
<td>824,725</td>
<td>269,270</td>
<td>32.7</td>
</tr>
<tr>
<td>Paper and allied products</td>
<td>488,101</td>
<td>164,808</td>
<td>33.8</td>
</tr>
<tr>
<td>Textile mill products</td>
<td>615,322</td>
<td>262,108</td>
<td>42.6</td>
</tr>
<tr>
<td>Lumber and wood products</td>
<td>475,730</td>
<td>196,489</td>
<td>41.3</td>
</tr>
<tr>
<td>Transportation by air</td>
<td>312,931</td>
<td>94,856</td>
<td>30.3</td>
</tr>
<tr>
<td>Fabricated metal products</td>
<td>1,351,777</td>
<td>336,919</td>
<td>29.3</td>
</tr>
<tr>
<td>Furniture and fixtures</td>
<td>428,539</td>
<td>121,271</td>
<td>28.3</td>
</tr>
<tr>
<td>Hyd construction (not bldg)</td>
<td>517,969</td>
<td>124,610</td>
<td>24</td>
</tr>
<tr>
<td>Oil and gas extraction</td>
<td>330,841</td>
<td>76,525</td>
<td>23.1</td>
</tr>
</tbody>
</table>

Source: NIOSH, 1998
Lesson 13: Radiation & Noise

**Hearing Loss vs. Noise**
- Noise-induced loss additive to age-related loss
- Enter age correction...

![Graph showing hearing threshold levels with noise-induced loss compared to age-related loss](image)

**NIHL Claims**
- How much is your hearing worth in WA?
- WA doesn’t allow age-correction for claims
  - $10K maximum PPD payment for loss in 1 ear
  - $65K maximum PPD for both ears
- Differences in compensation for various occupations

**Ways Exposures Can Be Reduced**

![Hierarchy of Health and Safety Controls](image)
To Prevent Hearing Loss

Employ the Engineering Control Strategies:
- Substitution
- Treatment
- Isolation
- Shielding

Substitution

- Eliminate noise or use quieter sources
  - Don’t use this ...
  - When these will do!

Treatment

- Active noise control (ANC)
  - Not good for everything, but pretty darn cool!
**Isolation (Barriers)**

- Use distance as a barrier
  - Distance/location: your friend for noise
  - Sources away from reflective surfaces, workers
  - 2x source-worker distance = 6 dB less
  - Move out of corner = 6 dB less
  - Move from 1 reflective surface = 3 dB less

**Inverse Square Law**

- Use distance as a barrier
  - Distance/location: your friend for noise
  - Sources away from reflective surfaces, workers
  - 2x source-worker distance = 6 dB less
  - Move out of corner = 6 dB less
  - Move from 1 reflective surface = 3 dB less

**Shielding (PPE)**

- Hearing Protection Devices (HPDs): 4 C’s:
  - Comfort
  - Convenience
  - Communications
  - Cost
**Administrative Controls**

- Establish and label high noise zones, require HPD use
- Noise map: a good excuse to use crayons

**Other Developments in Hearing**

- Hearing aids: friend or foe?
- Outer and inner hair cell regeneration
  - Birds do it - why can’t we?
- Otoprotectants
  - A “morning after” pill?
HPD Issues

- Workers MUST have training, selection
- Most earplugs alter quality of sound at different frequencies
  - Exception: flat response
- Speak up - don’t mumble

Administrative Controls

- Schedule noise for fewest workers
- Maintain/repair/lube equipment
- Rotation/break/limit time
- Signs
- No Walkman headphones!

Non-Occupational Noise

- Employers interested in non-occupational exposure
- Lots of sensational media reporting
- Little evidence of non-occupational NIHL
- If high occupational exposure, non-occupational noise insignificant
**Non-Occupational Noise**

- Hearing can be damaged by non-occupational activities, of course... For example:
  - Shooting (especially without HPDs)
  - Active duty/Guard military service
  - Excessive exposure to noisy non-occupational activities
  - Ototoxic exposures
- Best way to prevent non-occupational NIHL?
  - Education received as part of HLPP

**Community Noise**

- Noise is consistently rated among the most annoying community issues in the US
- Lots of sources... Can anyone think of any?

- Approaches used to control occupational noise exposure also work for community noise
- One difference:
  - With occupational noise, we want to prevent NIHL
  - With community noise, want to prevent NIHL, health effects, AND annoyance
### Recommended Exposure Levels

<table>
<thead>
<tr>
<th>Effect</th>
<th>Effect Threshold</th>
<th>Situation</th>
<th>Metric</th>
<th>Level (dBA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Any Hearing Impairment</td>
<td></td>
<td>Occup</td>
<td>8-hr average</td>
<td>75</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Environ</td>
<td>Day-Night average</td>
<td>70</td>
</tr>
<tr>
<td>Hypertension</td>
<td></td>
<td>Occup</td>
<td>8-hr average</td>
<td>&lt;85</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Environ</td>
<td>Day-Night average</td>
<td>70</td>
</tr>
<tr>
<td>Ischemic heart disease</td>
<td></td>
<td>Environ</td>
<td>Day-Night average</td>
<td>70</td>
</tr>
<tr>
<td>Annoyance</td>
<td></td>
<td>Occup</td>
<td>8-hr avg</td>
<td>&lt;85</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Environ</td>
<td>Day-Night average</td>
<td>42</td>
</tr>
<tr>
<td>Performance</td>
<td></td>
<td>School</td>
<td>Day average</td>
<td>70</td>
</tr>
<tr>
<td>Sleep disturbance</td>
<td></td>
<td>Sleep</td>
<td>Night average</td>
<td>&lt;60</td>
</tr>
<tr>
<td>Sleep pattern</td>
<td></td>
<td>Sleep</td>
<td>Night average</td>
<td>40</td>
</tr>
<tr>
<td>Sleep quality</td>
<td></td>
<td>Sleep</td>
<td>Night average</td>
<td>&lt;60</td>
</tr>
<tr>
<td>Mood next day</td>
<td></td>
<td>Sleep</td>
<td>Night average</td>
<td>&lt;60</td>
</tr>
</tbody>
</table>

Adapted from Passchier-Vermeer, EHP 2000

### Conclusion

**Preventing Hearing Loss**
- Hearing loss = Safety hazard, social isolation
- Cannot be reversed with hearing aids, surgery, etc.
- About 10 million US workers have NIHL
- HLPPs (and especially noise controls) are best protection from NIHL
- Hearing loss NOT necessary for growing old
- Noise can be confusing, but there’s a solution to any exposure problem...

**Noise Control**

There are several ways to stop noise – or even selectively let desired sounds through
The Problem with Noise Controls

- Engineers will tell you that there's no way a non-engineer could possibly develop or implement an effective noise control
  
  Solution: avoid engineers at all costs!
- Controls CAN be developed, but they do require effort and resources, and (sometimes) technical knowledge
- Noise control development support critical

Questions

Next Lesson

Occ. Health & Safety and Accidents