Lesson 16A. Radiation

Hazards & Safety

February 24, 2005

L.B. Sandy Rock, MD, MPH
Science Division
BCC

Radiation Hazards and Safety

Radiation has been around since the beginning of time. All plants and animals are continuously bombarded by radiation.

Wilhelm C. Roentgen
(1845-1923)

- **Worked with "Crookes" tubes in late 1895.**
- **Crookes tubes are evacuated glass tubes with high DC voltage applied across them.**

Discovering X-Rays

- Roentgen discovers that a piece of paper coated with barium platino-cyanide glows several centi-meters away from the covered tube.

ENVIR 202: Lesson 16 4

X-Ray Photography

- Roentgen notices that; "if the hand be held before the fluorescent screen, the bones show darkly, with only faint outlines of surrounding tissues."

ENVIR 202: Lesson 16 5

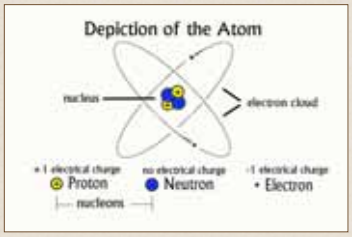
Early Radiation Injury

Radiation injury to the skin of a Spanish-American War soldier as a result of an x-ray examination (1896)

ENVIR 202: Lesson 16 6

Radiation

Radiation means matter or energy moving outward from a point of origin.

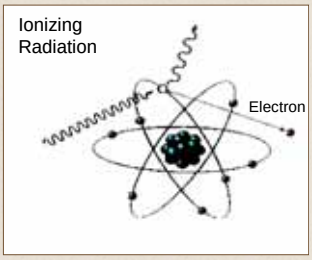


Ionizing radiations are generated by interactions occurring within the atom.

ENVIR 202: Lesson 16 7

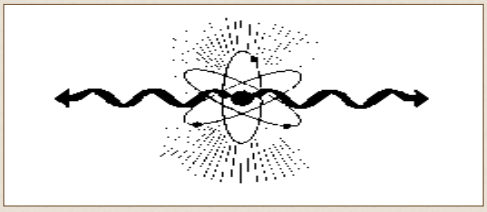
Ionizing Radiation

Ionizing radiation has enough energy to remove electrons from atoms.



ENVIR 202: Lesson 16 8

Ionizing Radiation

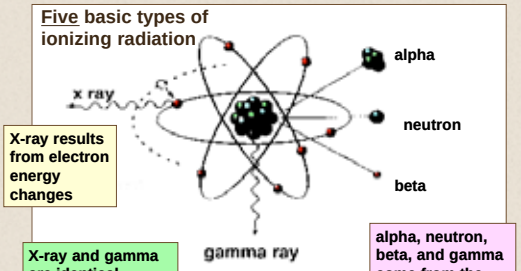


Atoms emit ionizing radiation to reduce excess energy and attempt to achieve stability.

ENVIR 202: Lesson 16 9

Types of Ionizing Radiation.

Five basic types of ionizing radiation



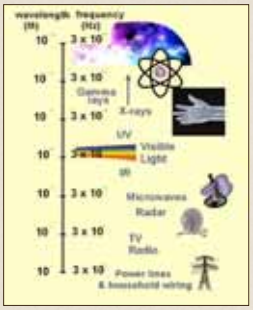
X-ray results from electron energy changes

X-ray and gamma are identical except for origin

alpha, neutron, beta, and gamma come from the nucleus

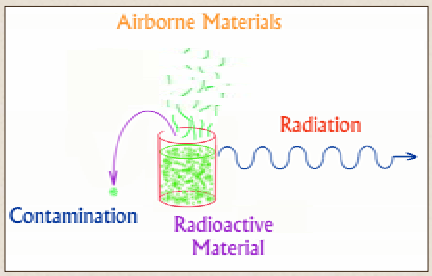
Electromagnetic Spectrum

Gamma rays and x-rays are forms of energy, similar to visible light and radio, but much more energetic.



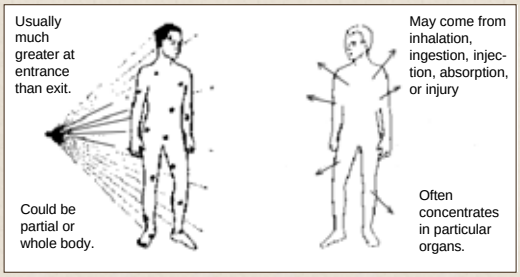
ENVIR 202: Lesson 16

Radiation Jargon



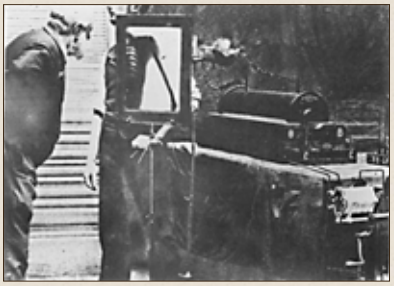
ENVIR 202: Lesson 16 12

Radiation Hazards



EXTERNAL versus INTERNAL RADIATION HAZARDS

Fate of Early Radiologists



ENVIR 202: Lesson 16 14

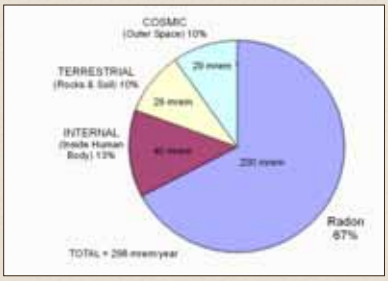
Radiologist Fingers

ENVIR 202: L 15

Radioactive Materials

Availability and use of radioactive materials "exploded" after World War II.

Background Radiation



Natural Background Radiation
[about 3 mSv (300 mrem) per year]

Annual Radiation Dose Limits

- **Occupational**
  - **0.05 Sv (5 rem or 5000 mrem) whole body**
  - **no individual organ dose greater than 0.5 Sv (50 rem)**
  - **Skin and extremities = 0.5 Sv (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)**

ENVIR 202: Lesson 16 18

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).**

ENVIR 202: Lesson 16 19

Radiation Effects

- **Acute/High Level Radiation Effects in Humans**
  - **Radiation Burns (over 2 Sv or 200 rem) – local or whole body**
  - **Keloids – Thick scars in healed burns**
  - **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?**

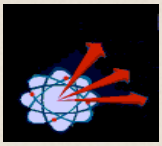
ENVIR 202: Lesson 16 20

Radiation Effects

- **Types of Low Level Radiation Induced 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 – about 0.8% lifetime chance of death after 0.1 Sv (10 rem) acute exposure. Less for chronic exposures. Background rate of cancer death is about 20%**

ENVIR 202: Lesson 16 21

Radiation Protection

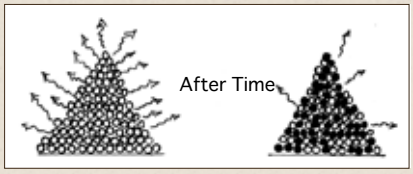


- Radiation Protection puts many scientific principles and techniques into practice.

ENVIR 202: Lesson 16 22

Radiation Protection

RADIOACTIVE DECAY

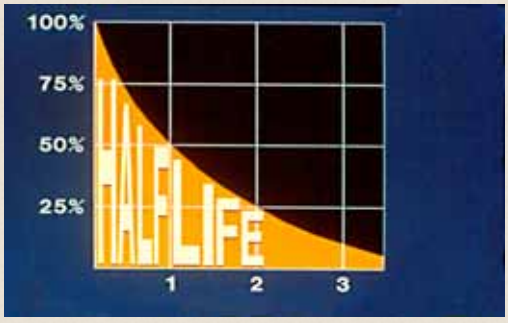


Pure Sample
Full Activity

Decayed Sample
Lower Activity

Radiation Protection for Both Internal and External Sources

Radioactive Decay



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?

ENVIR 202: Lesson 16 25

Treatment?

- Not an option. Attempts have been made to "irradiate" radioactive materials to turn them into different radioisotopes with shorter half-life.
- Success is poor, and by-products are produced with long half-lives.
- If someone suggests that you invest in a radioisotope treatment scheme – save your money!

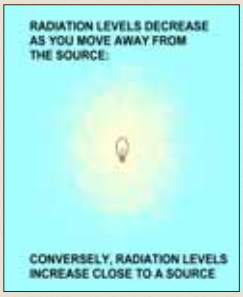
ENVIR 202: Lesson 16 26

Isolation/Burial

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

ENVIR 202: Lesson 16 27

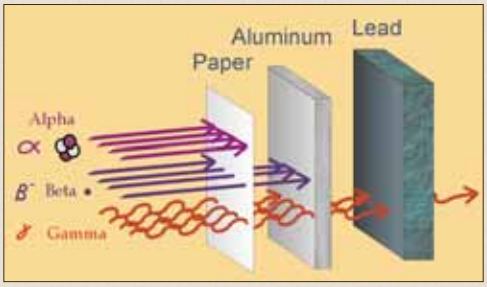
Change in Radiation Intensity with Distance



- Inverse Square Law: $1/r^2$ relationship
- For example; doubling your distance cuts exposure to 1/4, and tripling distance cuts exposure to 1/9.

ENVIR 202: Lesson 16 28

Penetration Ability



ENVIR 202: Lesson 16 29

Ways to Reduce External Exposure

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

ENVIR 202: Lesson 16 30

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.

ENVIR 202: Lesson 16 31

Methods to Reduce Internal Intake

Continued

- 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.

ENVIR 202: Lesson 16 32

Radiation in the Workplace

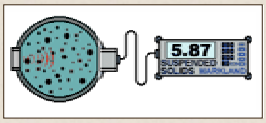
Research

Medicine

ENVIR 202: Lesson 16

Radiation in the Workplace
Continued

Measurement and Quality Control



Static Control

34

Man-Made Radiation in the Environment

Biomedical/Industrial wastes or byproducts

Lost Sources

ENVIR 202: Lesson 16 35

Man-Made Radiation in the Environment Continued

Active Production or Processing Sites

Closed/Abandoned Production or Processing Sites

ENVIR 202: Lesson 16

Dirty Bombs?

Radiological Dispersal Devices

Lesson 16B. Noise

Hearing Loss Prevention

February 24, 2005

L.B. Sandy Rock, MD, MPH
Science Division
BCC

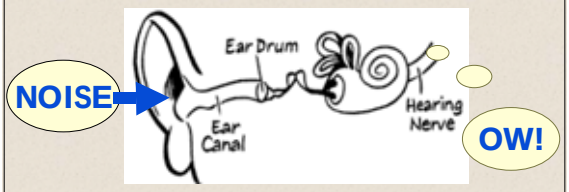
Lesson 15. Noise

Hearing Loss Prevention

February 24, 2004

L.B. Sandy Rock, MD, MPH
Science Division
BCC

Hearing Loss



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

ENVIR 202: Lesson 16 41

The Problem

- Why noise doesn't get much attention:
  - Lots of dangerous jobs in US
  - Acute hazards are priority
  - Chronic hazards easier to ignore…

ENVIR 202: Lesson 16

Noise

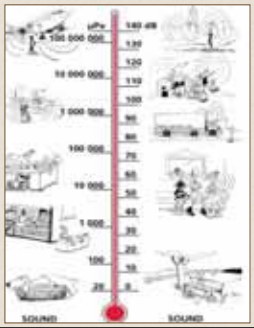
- What the heck is noise, anyway?
- Is it…
  - Neighbor's dog barking at 2AM?
  - Airliners flying over your house?
  - Classmate snoring next to you?
- YES! It's all this and more!

Noise Continued

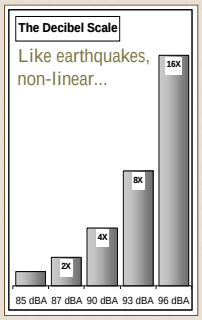
- Unwanted sound (vibrations in air)
- Measured by: sound pressure (loudness)
  - decibels (dB)
- And: frequency (pitch)
  - hertz (Hz) - vibrations per second

Why Decibels?

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

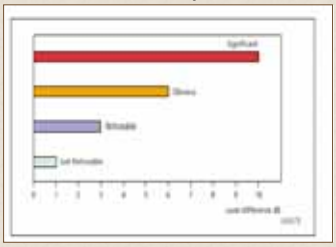


Decibels



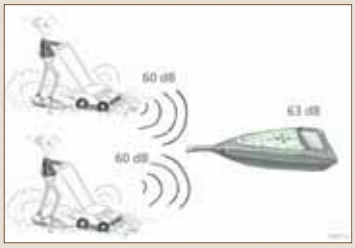
The decibel: funky, but useful

100 dB=10x90 dB, 100x80 dB



Addition of Decibels

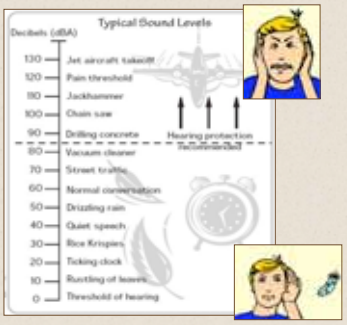
Don't add arithmetically …



ENVIR 202: Lesson 16 47

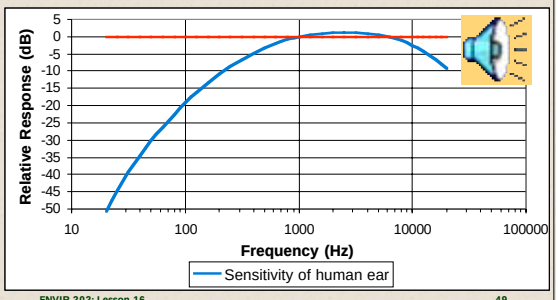
Noise Levels

Noise Levels of some familiar sounds



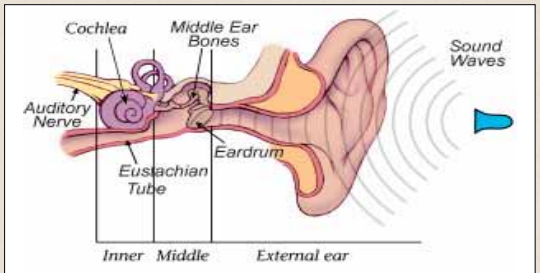
ENVIR 202: Lesson 16 48

Frequency is Important, Too ...



ENVIR 202: Lesson 16 49

How We Hear



Anatomy of the Ear

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

ENVIR 202: Lesson 16 51

Types of Hearing Damage

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

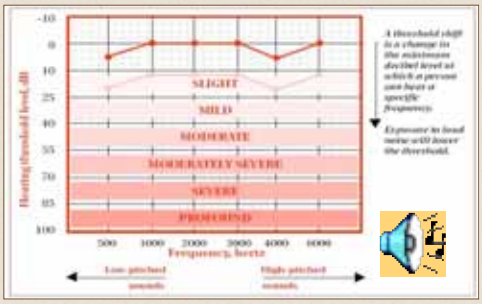
ENVIR 202: Lesson 16 52

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

ENVIR 202: Lesson 16

How We Measure Hearing



Hearing Loss

Hearing loss is frequency-specific

Certain frequencies are considered indicative of NIHL

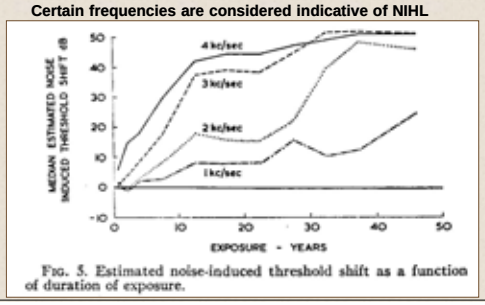
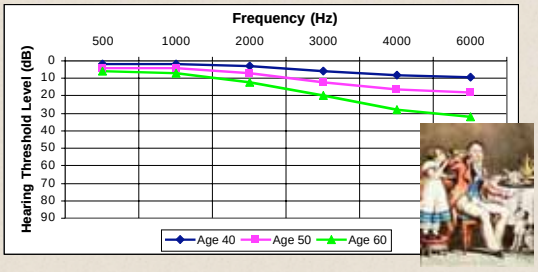


FIG. 5. Estimated noise-induced threshold shift as a function of duration of exposure.

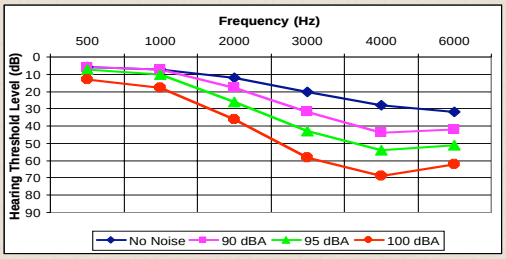
Age-related Hearing Loss

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



Hearing Loss vs. Noise

- **Noise-induced loss additive to age-related loss**
- **Enter age correction…**



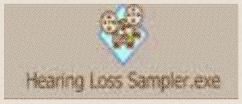
Effects of **NIHL**

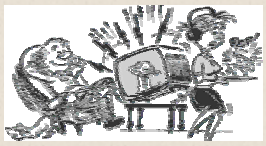
- NIHL affects high frequency hearing first
- NIHL makes it harder to communicate:
  - On the job
  - In situations w/ background noise (jobsite, restaurant)

ENVIR 202: Lesson 16

Effects of **NIHL**

- NIHL may affect ability to work
- NIHL can make it difficult to hear critical warnings:
  - Back-up alarms
  - Traffic on a street





ENVIR 202: Lesson 16

Effects of **NIHL**

- NIHL can:
  - Contribute to accidents, injuries
  - Lower self-esteem
  - Make people more dependent on others
  - Damage relations with friends, family
  - Make it hard to concentrate…

ENVIR 202: Lesson 16 60

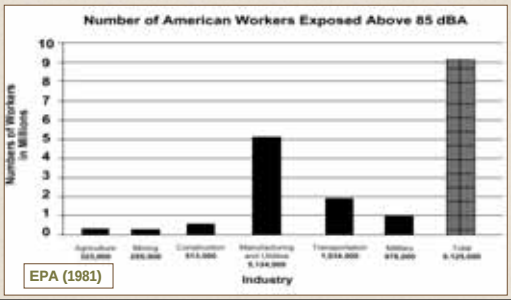
Other Effects of Noise

- 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

61

Noise Exposure Estimates

Who do YOU think might be exposed to too much noise?



EPA (1981)

Top 10 SICs

by % workers >85 dBA

Economic Sector	Total no. production workers	No. noise-exposed	% noise-exposed
Tobacco products	106,399	57,764	54.3
Primary metals	824,725	269,270	32.7
Paper and allied products	488,101	164,808	33.8
Textile mill products	615,322	262,108	42.6
Lumber and wood products	475,730	196,489	41.3
Transportation by air	312,931	94,656	30.3
Fabricated metal products	1,151,777	336,919	29.3
Furniture and fixtures	428,539	121,271	28.3
Hvy construction (not bldg)	517,969	124,610	24
Oil and gas extraction	330,841	76,525	23.1

Source: NIOSH, 1998

63

Other things that can Damage Hearing

- Ototoxic substances:
  - Aminoglycoside antibiotics, chemotherapy
  - Some metals (lead, arsenic, tin)
  - Solvents (toluene, benzene, styrene)
  - Carbon monoxide, hydrogen cyanide
  - Cigarette smoke (duh)
  - Even aspirin!
- Hand-arm and whole-body vibration

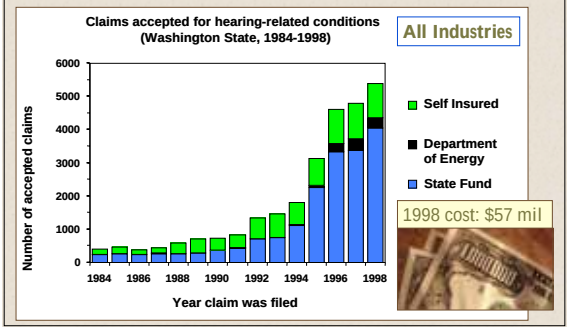
ENVIR 202: Lesson 16 64

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?

ENVIR 202: Lesson 16

Hearing Loss Claims in WA



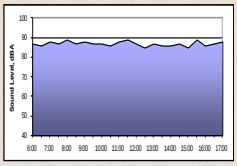
NIHL Claims

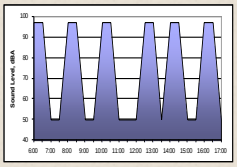
- How much is *your* hearing worth in WA?
- WA doesn't allow age-correction for claims
  - $10K maximum PPD payment for loss in 1 ear
  - $65K maximum PPD for both ears
- Differences in compensation for various occupations

ENVIR 202: Lesson 16 67

Noise Exposure Types

Continuous **Intermittent**



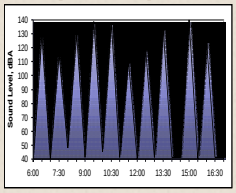


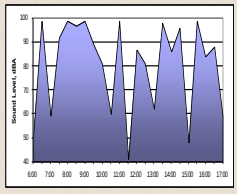
General scientific consensus on effects on hearing

ENVIR 202: Lesson 16 68

Noise Exposure Types

Impact/Impulse **Combination**





No scientific consensus on effects on hearing

ENVIR 202: Lesson 16 69

Ways to Measure Noise

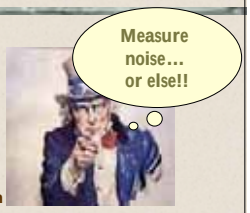
- Sound Level Meter
  - Area/personal measurements, point-in- time levels
  - Cheap, easy, good for continuous noise, immediate HPD needs
- Dosimeter
  - Area/personal measurements
  - Point-in-time or average level, continuous or variable noise
  - Expensive, but low labor




ENVIR 202: Lesson 16

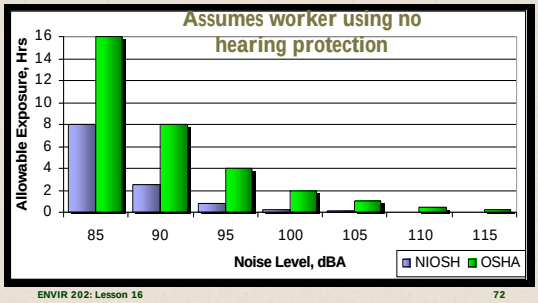
US Noise Standards

- 1936: Walsh-Healey Act
- 1968: ACGIH TLV
- 1971: OSHA PEL
- 1971: EPA ONAC
- 1974: NIOSH REL
- 1981: No more EPA ONAC
- 1983: OSHA Hearing Conservation
- 1990s: revised ACGIH TLV, NIOSH REL, MSHA PEL



ENVIR 202: Lesson 16 71

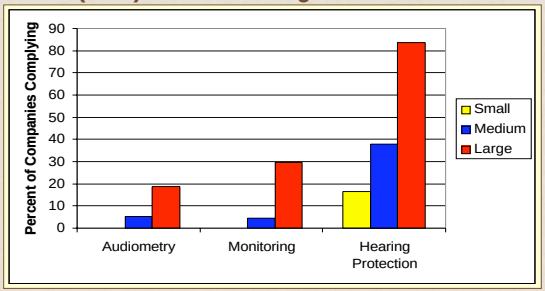
Noise Standards
OSHA vs. NIOSH



ENVIR 202: Lesson 16 72

Hearing Conservation in Industry

NOES (1983) national findings:



OSHA Citations & Fines

- Oct 1999 - Sept 2000
  - 692 OSHA inspections, 1475 citations for noise exposure
  - Manufacturing sector got 1284 of these citations, $725,000 in fines
  - $725,000÷1284=$565 per citation
- Cheaper to ignore HL than address it?
  - No; fines don't account for worker suffering, claims costs, etc

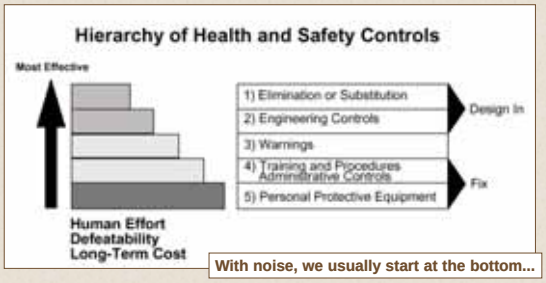
16 74

On to Hearing Loss Prevention!

- Goal: reduce or eliminate noise exposure
- What's in a Hearing Loss Prevention Program?
  - Noise exposure monitoring
  - Controlling/reducing noise exposures
  - Hearing protector selection, fitting and use
  - Audiometric testing
  - Employee education & training
  - Program evaluation
- Protects:
  - Employer from claims, employee from NIHL

ENVIR 202: Lesson 16

Ways Exposures Can Be Reduced

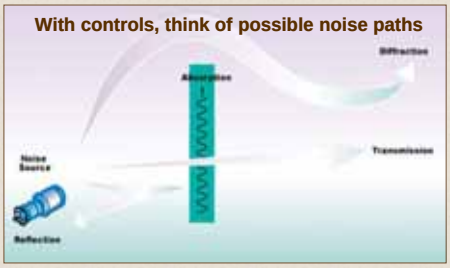


With noise, we usually start at the bottom...

ENVIR 202: Lesson 16 76

Noise Control

With controls, think of possible noise paths



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

ENVIR 202: Lesson 16 78

We used to have this support!

- US EPA Office of Noise Abatement and Control, 1972-82
  - Developed noise standards, researched noise controls, promoted Buy Quiet programs
  - Bill before congress every year to re-fund
- Europe committed in 2000
  - Noise levels specified for various equipment
  - Controls mandatory
  - Will make 50% of current construction equipment ineligible for EU sale in 2006

ENVIR 202: Lesson 16 79

To Prevent Hearing Loss

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

ENVIR 202: Lesson 16 80

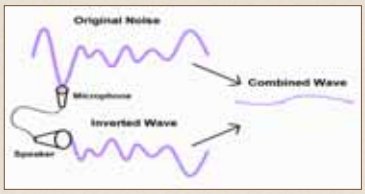
Substitution

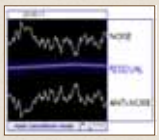
- Eliminate noise or use quieter sources
  - ← Don't use this ...
  - ↓ When these will do!

ENVIR 202: Lesson 16 81

Treatment

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



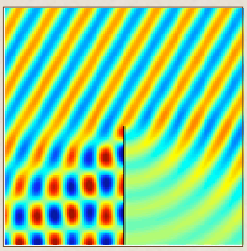


Isolation

- Enclose the noise source behind a barrier

ENVIR 202: Lesson 16 83

Barriers

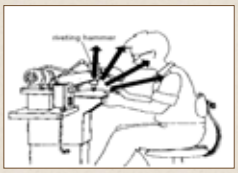


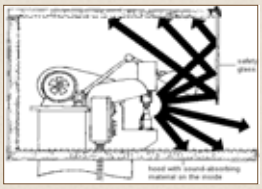
ENVIR 202: Lesson 16

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



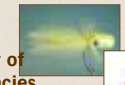


Shielding

- Hearing Protection Devices (HPDs):
- 4 C's:
  - Comfort
  - Convenience
  - Communications
  - Cost

HPD Issues

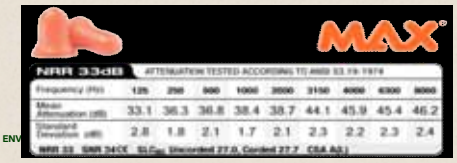
- Workers MUST have training, selection
- Most earplugs alter quality of sound at different frequencies
  - Exception: flat response
- Speak up - don't mumble



ENVIR

Noise Reduction Rating

- Summary of HPD attenuation across various test frequencies achieved by test subjects
- Required by EPA regulation to appear on all HPDs sold in US
- Includes mean attenuation and variability data



ENV 89

Administrative Controls

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

ENVIR 202: Lesson 16 90

Administrative Controls

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

ENVIR 202: Lesson 16

Administrative Controls

- Signs
  - Some signs are better than others…

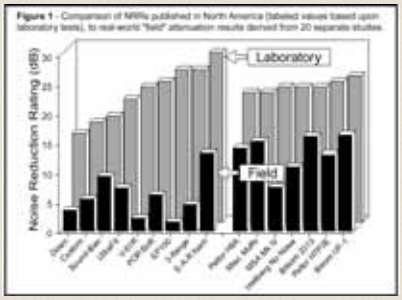
BAD

BETTER

GOOD

ENVIR 202: Lesson 16 92

Effectiveness



NRRs in the lab versus the field

93

Shielding

- When to Wear Hearing Protection
  - Whenever exposure likely to exceed 85 dBA - at work OR home
  - When using loud equipment When working in areas where loud equipment is being used
  - When you have to shout to be heard by someone 3 ft away

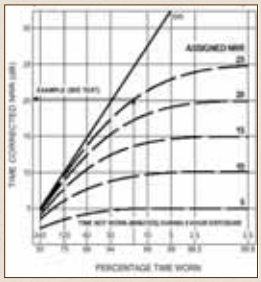
ENVIR 202: Lesson 16 94

But How Often are **HPDs** Used?

Different people have different patterns of use of personal protective equipment like HPDs…

Protection Reduced if **HPD** Not Used…

- The more time an HPD isn't worn during noise exposure, the less it reduces the average exposure level
- If it's worn less than 50% of exposure time, might as well not wear it at all



ENVIR 202: Lesson 16 96

Audiometric Testing

- Pre- and post-employment and annually best
  - but occasionally is better than never!
- Best opportunity for education about NIHL, need for protection
- If this is only HLPP effort:
  - Hearing loss documentation
- NIHL now must be reported to OSHA

ENVIR 202: Lesson 16 97

Education

- Employees need motivation and training
  - Annually, or even better, delivered regularly in small chunks
  - Needs to cover basics:
    -Noise levels
    -Noise controls
    -Hearing loss
    -Audiometry
    -HPD use/care

ENVIR 202: Lesson 16

HLPP Program Evaluation

- As with all programs, HLPP must be evaluated on an ongoing basis
- May not like what you see…
  - But that's all the more reason to do evaluation and institute improvements where necessary
- Look for:
  - NIHL rates, number workers exposed above 85 dBA, average exposure levels, HPD use, etc

ENVIR 202: Lesson 16

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



ENVIR 202: Lesson 16

Non-Occupational Noise

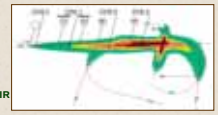
- Hearing can be damaged by non-occupational activities, of course… For example:
  - Shooting (especially without HPDs)
  - Active duty/Guard military service
  - Excessive exposure to noisy non-occupational activities
  - Ototoxic exposures
- Best way to prevent non-occupational NIHL?
  - Education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

ENVIR 202: Lesson 16 101

Community Noise

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





ENVIR 102

Community Noise

- 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

ENVIR 202: Lesson 16 103

Recommended Exposure Levels

Effect	Situation	Effect Threshold Metric	Level (dBA)
Any Hearing Impairment	Occup Environ	8-hr average 24-hr average	75 70
Hypertension	Occup Environ	8-hr average Day-Night average	<85 70
Ischemic heart disease	Environ	Day-Night average	70
Annoyance	Occup Environ	8-hr avg Day-Night average	<85 42
Performance	School	Day average	70
Sleep disturbance			
Sleep pattern	Sleep	Night average	<60
Sleep quality	Sleep	Night average	40
Mood next day	Sleep	Night average	<60

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…

ENVIR 202: Lesson 16 105

Questions

ENVIR 202: Lesson 16 106

Next Lesson

Ionizing Radiation

ENVIR 202: Lesson 16 107

Questions

ENVIR 202: Lesson 16 108

Next Lesson

Human Settlement & Health

ENVIR 202: Lesson 16 109