Noise: Impact on Hearing; Regulation

EOH 466A
Fall 2008

Mechanism of Hearing

• Sound waves collected, focused by the outer ear.
• Humans have little control over muscles in outer ear. Many animals have the ability to move ears, so they can be more efficient collectors of sound energy.
• Eardrum transforms sound energy into kinetic energy at the ear drum:
  – ossicles transfer energy to the inner ear. hammer (malleus), anvil (incus) and stirrup (stapes).
Mechanism of Hearing

• The middle ear serves to amplify the energy in sound waves; movement of structures is amplified since eardrum is large relative to base of stirrup.

Mechanism of Hearing

• Inner ear: Contains semicircular canals, used in sense of balance, and cochlea.
Hearing Damage

- Hearing can deteriorate for several reasons:
- Nosoaucusis: Damage from disease or injury
- Presbycusis: Aging
- Socioacusis: Exposure to noise. NIHL (Noise Induced Hearing Loss)
Hearing Damage

- Audiogram: the way in which hearing is evaluated. OSHA regulation requires that hearing be tested at 500, 1000, 2000, 3000, 4000 and 6000 Hz. Hearing loss is shown by an increase in the intensity of the softest tone perceived by the subject at a particular frequency, relative to reference values.

Hearing Damage

- A change in a person's ability to hear a tone (in other words, a change in the threshold at which a tone is audible to an individual) is referred to as a threshold shift.
Hearing Damage

• The effects of exposure to noise may be temporary. For a few hours after exposure to loud noise, a person may feel a 'ringing in the ears', and be less sensitive to noise. This can be measured, and is referred to as a Temporary Threshold Shift (TTS). After several hours, the ears recover to the acuity present before exposure to noise.

Hearing Damage

• Repeated exposure to high levels of noise will result in permanent hearing damage. Hearing acuity is permanently reduced, relative to that present before exposure started. This effect is referred to as a Permanent Threshold Shift (PTS).
  – Impairment refers to a specific permanent threshold shift. This can be defined in different ways. Average dB shift at 0.5-1-2 kHz; 1-2-3 kHz; 1-2-3-4 kHz are examples of this definition.
Mechanisms of Hearing Loss

• Conductive hearing loss: results from interference with sound energy transfer from environment to the inner ear. Does not result from exposure to noise.

Audiograms Showing Conductive Hearing Loss
Mechanisms of Hearing Loss

• Sensorineural hearing loss: results from damage to cochlea, auditory nerves or both. Can result from exposure to noise.

• Noise-induced hearing loss: Results from chronic exposure to industrial noise (broad frequency).
  • PTS will develop, starting at a frequency of 4000 Hz. If exposure to noise continues, PTS will increase, and frequencies above and below 4000 Hz included.
Audiograms Showing Sensorineural Hearing Loss

Effects of Hearing Loss

- Hearing loss interferes with the ability to understand speech: as PTS develops in frequencies below 3000 Hz (speech sounds), clarity of hearing is reduced. Of course, enjoyment of music may be compromised.
Mechanisms of Hearing Loss

- Combined: Results form a combination of factors, so both types of hearing loss result.

Mechanisms of Hearing Loss

- Presbycusis: As the body ages, the ear becomes less sensitive to high frequency noises. This loss is greater for sounds of higher frequency, but affects all frequencies to some degree. Significant hearing loss occurs for sounds above 4000 Hz.
Effects of Noise on Hearing

- Noise levels of concern: Estimates vary depending on definition of impairment. The magnitude of excess risk, after correction for age-related nearing loss (average prediction)
  - 90 dBA 25 %
  - 85 dBA 8 %
  - 80 dBA 1 %

Non-auditory Effects of Noise

- Stress
- Decreased performance
- Increased fatigue
- Hypertension
Noise Regulations

- OSHA standard for noise exposure allows an 8-hr TWA exposure of 90 dBA. The standard follows a '5 dB doubling rate'. For every 5 dB increase in noise exposure, allowed duration is cut in half. Time (hours) = \( \frac{8 \text{ hours}}{\frac{L-90\text{dBA}}{2^{\frac{5\text{dBA}}{}}}} \)

OSHA PEL

- The OSHA standard has been left at 90 dBA, 5 dBA exchange rate and 90 dBA threshold.
- NIOSH and ACGIH recommend that the PEL be reduced to 85 dBA, 3 dBA exchange rate and 80 dBA threshold.
Noise Regulations

• Noise Dose

\[
\text{Dose, } \% = \sum \frac{\text{Time exposed}}{\text{Time allowed}} \times 100
\]

Noise Exposures

• Population exposed to noise in the US (occupational)
  – At or above 90 dBA: 5 million (4.5 % of workforce)
  – At or above 85 dBA: 30 million (27 % of workforce)
Hearing Conservation Amendment

• Hearing Conservation Amendment (HCA). The HCA requires a formal program designed to protect the hearing of workers exposed to noise at levels greater than 85 dBA, 8 hour TWA.
  – Use the same criterion as the PEL, but 80 dBA Threshold. A Dose of 50 % or above means the HCA applies.

Hearing Conservation Amendment

• HCA does not apply to oil and gas drilling workers, or to construction workers. Separate standard applies.
• HCA is intended to supplement the PEL for noise. It established an action level for noise, similar to other new health standards, requiring exposure monitoring and audiometric testing of workers exposed to noise above 85 dBA, 8-hr TWA.
Hearing Conservation Amendment

• Components of HCA:
  – Monitoring of worker exposure to noise
    • Monitoring may employ a dosimeter or a hand held sound level meter.
    • All noise greater than 80 dBA must be included in monitoring for the HCA.

Hearing Conservation Amendment

• Audiometric testing is required for all workers exposed to noise above 85 dBA.
• A baseline audiogram must be taken for all new employees within 6 months of hire
  – Baseline should be preceded by 14 hours of quiet
  – alternative is to wear hearing protectors and retest if baseline shows hearing impairment.
Hearing Conservation Amendment

- A qualified person (audiologist, otolaryngologist or physician) must supervise audiometric program.
- Trained technicians must perform testing.

Hearing Conservation Amendment

- A standard threshold shift is defined by the HCA as a change in hearing acuity averaging greater than 10 dB at 2000, 3000 and 4000 Hz in either ear, relative to baseline.
- A STS does not indicate that a compensable hearing loss has occurred.
Hearing Conservation Amendment

• Hearing protectors are required for workers who
  – are exposed to noise above 90 dBA.
  – are exposed to noise above 85 dBA, and have suffered a STS.
  – are new employees, and have not had baseline within 6 months of hire.
  – must be provided for all workers exposed to noise above 85 dBA who wish to wear them.

Hearing Conservation Amendment

• Hearing protector selection.
  – Noise Reduction Rating (NRR) may be used to assess utility of hearing protector:
    • dBC - NRR = dBA (estimated exposure)
    • dBA - NRR + 7 = dBA (estimated exposure).
  – Because protectors may not work as designed, the NRR should be 'derated' when estimating protection. OSHA: derate all NRR by 50 %. NIOSH: muffs 25 %; formable plugs 50 %; all other plugs 70 %.
Hearing Conservation Amendment

Table 1 - Application of OSHA specified computation for an HPD with a labeled NRR of 21 dB

<table>
<thead>
<tr>
<th>NRR for use with dBC measurements</th>
<th>NRR for use with dBA measurements</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADEQUACY per hearing Cons. Amendment, Appendix G</td>
<td>21</td>
</tr>
<tr>
<td>RELATIVE PERFORMANCE vs. noise controls</td>
<td>21 / 2 = 10.5</td>
</tr>
</tbody>
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EXAMPLE: Unprotected Time-Weighted Average (TWA) exposure = 100 dBA. To assess ADEQUACY per Appendix G, the protected TWA is computed as:
100 dBA - 14 dBA dBA, current hearing protection is legally adequate.
To assess RELATIVE PERFORMANCE, i.e. comparison of field attenuation to engineering or administrative controls, the protected TWA is computed as: 100 dBA - 7 dBA = 93 dBA since this exceeds 90 dBA, feasible engineering controls must be implemented.
NOTE: when using Harris and plug together, OSHA adds 5 dB to NRR of lightly raised HPD. For field effectiveness, 5 dBA is added after 50% adjustment, as in:
NRR_{HPD} = 25; NRR_{appl} = 21; field NRR for use with dBA = [(25 - 7)/2] + 5 = 16 dBA.

Hearing Conservation Amendment

• Training of workers in effects of noise, use and effectiveness of hearing protectors, practice and meaning of audiometric testing. Training should occur at least annually.
Hearing Conservation Amendment

- Record keeping: retain noise exposure surveys should be retained for at least two years; audiometric testing data retained for duration of employees service.

Office Noise Standards (not regulations)

- Permit communication, telephone conversation
- PSIL: Preferred Speech Interference Level
  - Average 500, 1000, 2000, 4000 bands
  - PSIL = dBA - 7 (estimate)
  - Phone conversation
    - < 60 OK
    - 60-75 difficult
    - 76-85 very difficult
    - > 85 impossible.
Office Noise Standards (not regulations)

- ASHRAE (American Society of Heating Refrigeration and Ventilation Engineers) guidelines Room Criteria Curves
  - Cover a wide range of frequencies; measure noise across frequencies and compare to maximum recommended noise levels published by ASHRAE, for specific room functions.

Community Noise

- Sound level, frequency spectrum and time of day are factors.
- dBA readings often used as octave band meters may not be available.
- EPA, HUD have guidelines; local ordinances exist. EPA noise office not funded.
- Microphone and chart recorder may be used to measure noise over 24 hours.
- Compare day (7 - 7), Evening (7 - 10) and night (10 - 7) levels. Most complaints: Night.
Community Noise

- descriptors $L_{\text{max}}$, $L_{\text{min}}$, $L_n$ (% time particular noise level is exceeded, eg $n = 90$); $L_{\text{eq}}$ (average)
- EPA recommends a complex calculation to give a 24 hour average, discounting night time noise by 10 dBA. $L_{dn}$.
Community Noise

- HUD uses $L_{dn}$ to evaluate impact of external noise on indoor environment; subtract 15 - 25 dBA if windows closed, or 5 - 10 dBA if windows are open.
  - Acceptable < 65 dBA
  - Normally unacceptable 65 - 75 dBA
  - Unacceptable > 75 dBA (for housing)

Community Noise

- EPA Levels (1974)
  - 55 dB $L_{dn}$ outdoors
  - 45 dB $L_{dn}$ indoors
- WHO (1980)
  - 50 – 55 dBA L (9 hrs) outdoor / day
  - 45 dBA L (9 hrs) outdoor / night
  - 30 dBA L (24 hrs) bedrooms
  - 45 dBA L (24 hr) bedrooms
Community Noise

- HUD (24 CFR 51.103)
  - 65 dB outdoors – general construction
  - > 65 – 75 dB outdoors – acoustical sound isolation
  - > 75 dB outdoors – unacceptable, only with acoustical sound isolation and overriding benefits

Community Noise

- FHWA (23 CFR 772)
  - 57 dBA (1 HR), 60 dBA
    - Lands on which serenity and quiet are of extraordinary significance.
  - 67 dBA, 70 dBA
    - Picnic areas, recreation areas, residences, motels, schools, churches, libraries, hospitals
  - 72 dBA, 75 dBA
    - Developed lands not in categories above
Community Noise

- FAA (14 CFR 150, Appendix A)
- Less than 65 dB $L_{dn}$ yearly average
  - Compatible for all uses
- 65 – 70 dBA
  - Compatible for commercial building use.
  - Public building use with 25 dBA building envelope aircraft noise reduction.
  - Not compatible for residential use. Interior acceptable with 25 dB NR.

Community Noise

- FAA (continued)
- 75 – 80 dBA
  - Commercial building use with 25 dBA building envelope noise reduction.
  - Not compatible for public building or residential use, but interior acceptable with 35 dBA building envelope noise reduction (over riding importance)
- > 80 dBA
  - Not compatible for commercial, public or residential use buildings.