References

American Industrial Hygiene Association website https://www.aiha.org/about-ih/Pages/default.aspx; accessed 7/24/2014.

ATI. (2014). Real-Time In-Ear Datalogging. ONR Dosimetry: Benchtop to Operations Workshop.

DODI 6055.12. (December 3, 2010). Hearing Conservation Program.

Fischer, R., & Komrower, J. (2012). Shipboard Noise Control. Noise Induced Hearing Loss Program Review.

Komrower, J. M. (2012). Noise Control in Hydroelectric Powerplants. Noise Induced Hearing Loss Program Review.

MIL-STD-1474E. (2014). Department of Defense Design Criteria for Noise Limits.

Royster, L. H., Berger, E. H., & Royster, J. D. (2003). Noise Surveys and Data Analysis. In E. H. Berger, L. H. Royster, J. D. Royster, D. P. Driscoll, & M. Layne, The Noise Manual, 5th Edition (pp. 165-244). Fairfax: American Industrial Hygiene Association.

Damage Risk Criteria for Twenty-Four Hour Noise Exposures

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Disclaimer: The findings and conclusions of this report are those of the author and do not necessarily represent the views of the National Institute for Occupational Safety and Health.

Why it is important?

U.S. Occupational regulations limit the eight hour exposure of workers to noise to 90 dBA or less. The National Institute for Occupational Safety and Health (NIOSH) recommends that workers not be exposed to more than 85 dBA for more than 8 hours per day. The NIOSH Criteria Document (1998) in Table 1-1 lists a Permissible Exposure Level of 80 dBA for 25 hours 24 minutes. There are occupations and situations where workers may be in an environment in which exposures may last 24 hours or even longer.

What is known?

Long term noise exposure research was primarily conducted in the period from 1960-1980 to determine contributing factors to noise-induced permanent threshold shift (PTS). Since it is unethical to induce a PTS in a human all of this research was conducted by inducing a TTS of 30 dB or less. (Parallel animal PTS research was being conducted at this time.) The overarching assumption is that TTS measured at 2 minutes post-exposure is a predictor of noise-induced PTS. After 8-16 hours of continuous noise exposure temporary threshold measures asymptote producing an Asymptotic Threshold Shift (ATS). The assumption is that because the ear is reacting to acoustical energy the ultimate PTS will not exceed the ATS. It has been suggested that ATS predicts the level of PTS after 10-20 years of constant occupational noise exposure. For a comprehensive review of the logic associated with the ATS research Melnick (1991) is recommended. In the late 1970's the Air Force in conjunction with EPA and NASA did a series of controlled 24 and 48 hour noise exposures. Nixon et al. (1977) did long duration (24- and 48-hour) noise exposures of 85 dBA pink noise. They found that in both exposures, ATS occurred at 8-16 hours into the exposure but that recovery from ATS was prolonged in the 48 hour exposure. Based on their data the authors suggest that a noise exposed person should be given the same amount of time to recover in quiet as the time exposed. Based on their exposures they recommend that long-term exposures in excess of 90 dBA should be avoided.

In a second Air Force study Stephenson et al. (1980) exposed college age males to pink noise for 24 hours at levels of 65, 70, 75, 80 and 85 dBA. They found the level at which ATS was not detectable (less than 5 dB) lies between 75 and 80 dBA. They confirmed the Nixon et al. observation that the recovery time course about matched that of the course to develop asymptotic threshold shift even when ATS levels were lower.
In a third Air Force study Johnson et al. (1976) exposed volunteers for 24 hours to the equivalent of 85 dBA pink noise presented with interruptions. The interruptions were from seconds to minutes. They noted that the time to reach ATS was about the same in all groups but the level of ATS was less than the previous continuous noise level. Again, they found that recovery from TTS required as much time as the initial exposure.
In 1974 the Environmental Protection Agency (EPA) in appendix C of their document Information on levels of environmental noise requisite to protect public health and welfare with an adequate margin of safety (1974) worked through the logic of a 24 hour environmental noise damage risk criterion. These recommendations were predicated on several significant assumptions. The first assumption is the Temporary Threshold Shift assumption described above. (Another Pharmaceutical Intervention in Hearing Loss [PHIL] group is examining the relationship between TTS and PTS.) The second assumption is the Equal Energy Hypothesis. This hypothesis states that the ear integrates sound energy: time and acoustical energy can be interchanged to produce equivalent TTS. Much of the TTS work emphasized 4 kHz because it is more susceptible to both temporary and permanent threshold shift than other audiometric frequencies. The authors use occupational epidemiological data from noise exposed workers. This amounted to a 40 year exposure to 8 hour per day noise with 16 hours of "rest." Based on cross sectional data the EPA determined that a 40 year 8 hour daily maximum exposure level of approximately 73 dBA will protect the population against an NIPTS of more than 5 dB. Intermittency of the noise reduces the noise hazard. The authors

suggest a 5 dB correction factor if the noise, like most environmental noises, drops to 65 dB at least 10% of the time. This produces a maximum exposure level of 78 dBA. Based on the Equal Energy Hypothesis and a number of calculations the EPA determined that a noise level of 71.4 dBA of intermittent noise, 24 hours per day for 365 days per year is a reasonably safe exposure. They rounded to 70 dB for ease.

Based on the Air Force studies, once exposed to noise in an occupational setting, the worker should have a minimum of 8 hours of quiet. How quiet must the rest period be to obtain full recovery? Based on the research of Ward (1976) and others, consensus was that in order to recover from a noise induced TTS the worker should remain in an environment of less than 65 to 70 dB for 16 hours. This seemed to be the level at which no further TTS was observed and thresholds were returning to pre-shift levels.
In 2012 Flamme et al. (2012) had 286 civilian volunteers wear noise dosimeters round the clock for durations of 23 hours to 20 days (median 9.8 days). They found the median noise level was 79 dBA with 70% of the sample exceeding the EPA recommendation for acoustic rest. Based on their mid-west U.S. sample the authors concluded that a large proportion of the general public is exposed to noise levels that could result in long-term negative effects on hearing.
NASA (Goodman 2003) in designing the acoustic environment for the International Space Station had even more stringent guidelines. They allow a 60 dBA acoustical environment while the astronauts are working and 50 dBA limit while the astronauts are resting.

What is not known (research possibilities)?

Kujawa and Liberman's recent studies of TTS in the mouse and guinea pig (Kujawa and Liberman 2009, Lin, Furman et al. 2011) found that even TTS that resolves to pre-exposure threshold levels result in inner hair cell synaptic changes it is doubtful that any new long-term human laboratory studies inducing a TTS will be allowed in the foreseeable future. Human studies based on occupational exposures may be possible.
Exposures in excess of 48 hours: The longest laboratory studies of TTS have been 48 hours. The researchers in those studies indicated a reluctance to exceed 48 hours based on the time required for hearing to return to baseline. In reality there are noise exposures in military and civilian environments which may exceed 48 hours.
Exposures greater than 90 dBA: Johnson et al.(1976) showed that with intermittent noise exposures levels as high as 100 dB over 24 hours can produce TTS levels which resolve to baseline. Pushing beyond 90 dB is risking producing PTS in humans.
Values for quiet rest levels: Although there have been a number of guesses about the nose level at which rest must be to produce effective resolution of TTS there does not appear to be a definitive study. Levels from 78 dB to 65 dB have been suggested. NASA International Space Station design standards were developed not only to reduce hearing loss but also to reduce psychological and physiological stress (Goodman 2003).

Can these resting environments be produced by passive hearing protection or active noise cancellation?

Understanding the variability of threshold shift to a noise exposure: One of the big questions in noise-induced hearing loss is: why there is so much variability between individuals? It is often talked about as "iron" and "glass" ears. This variability seems in some respects to be genetic. However, even inbred mice show variability but to a lesser extent. It would allow for much better damage risk criteria if the source(s) of vulnerability to noise could be determined and accounted for.
Can a pharmaceutical intervention either protect or rescue the ear from long term exposures? It would be exciting to be able to reduce the level of ATS, or speed recovery of the ear from TTS by intervention of a pharmaceutical and thereby perhaps reduce PTS.

References

*Environmental Protection Agency (1974). Information on levels of environmental noise requisite to protect public health and welfare with an adequate margin of safety. Office of Noise Abatement and Control. Washington DC, US Government. **550/9-74-004:** 1-242.*

*Flamme, G. A., M. R. Stephenson, K. Deiters, A. Tatro, D. VanGessel, K. Geda, K. Wyllys and K. McGregor (2012). "Typical noise exposure in daily life." International Journal of Audiology **51**: S3-S11.*

Goodman, J. R. (2003). International Space Station Acoustics. NOISE-CON 2003, Cleveland, OH.

*Johnson, D., C. Nixon and M. Stephenson (1976). " Long-duration exposure to intermittent noises." Aviation Space and Environmental Medicine **47**(Sept): 987-990.*

*Kujawa, S. G. and M. C. Liberman (2009). "Adding Insult to Injury: Cochlear Nerve Degeneration after "Temporary" Noise-Induced Hearing Loss." Journal of Neuroscience **29**(45): 14077-14085.*

*Lin, H. W., A. C. Furman, S. G. Kujawa and M. C. Liberman (2011). "Primary Neural Degeneration in the Guinea Pig Cochlea After Reversible Noise-Induced Threshold Shift." Jaro-Journal of the Association for Research in Otolaryngology **12**(5): 605-616.*

*Melnick, W. (1991). "Human temporary threshold shift (TTS) and damage risk." J. Acoust. Soc. Am. **90**(1): 147-154.*

*National Institute for Occupational Safety and Health (1998). Occupational Noise Exposure, Revised Criteria 1998. DHHS. Cincinnati, OH**:** 1-105.*

*Nixon, C., D. Johnson and M. Stephenson (1977). "Asymptotic behavior of Temporary Threshold Shift and Recovery from 24 to 48 hour noise exposures." Aviation, Space and Environmental Medicine **48**(April): 311-515.*

*Stephenson, M. R., C. W. Nixon and D. L. Johnson (1980). "Identification of the Minimum Noise-Level Capable of Producing an Asymptotic Temporary Threshold Shift." Aviation Space and Environmental Medicine **51**(4): 391-396.*

Ward, W. D. (1976). A Comparison of the Effects of Continuous, Intermittent, and Impulse Noise. Effects of Noise on Hearing. D. Henderson, R. Hamernik, D. S. Dosanjh and J. H. Mills. New York, NY, Raven Press: 407-420.

Impulsive Noise

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Why are we interested in impulsive noise?

Short duration impulsive noise is typically generated by a release of pressure (impulse) or a collision of solid objects (impact). In animal models these noises have been shown to be more damaging to the ear than continuous noise of equal energy (Hamernik and Henderson 1974, Dunn, Davis et al. 1991, Hamernik, Ahroon et al. 1994). Impulsive noises are common in manufacturing, construction, public service and the military. All police and sheriff officers must qualify annually on firearms which generate impulsive noise.

What is an impulsive noise?

The US Occupational Safety and Health Administration (OSHA) definition of impulsive noise includes noises most researchers do not consider impulsive: "If the variations in noise level involve maxima at intervals of 1 second or less, it is to be considered continuous." That is, if maxima are 1 second or less, noises are considered impulsive. Most researchers would consider a noise impulsive if it is a single pressure peak typically lasting milliseconds to microseconds.

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