MODERN MUSIC-PLAYING DEVICES AS HEARING HEALTH RISKS

Brenda L. Lonsbury-Martin

and

Glen K. Martin

Research Service, Veterans Affairs Loma Linda Healthcare System
Loma Linda, California 92357

Noise-induced hearing loss (NIHL) is a disorder that is common throughout the industrialized world. Exposure to excessive sounds produces a complex set of harmful effects that happen painlessly and silently to the delicate inner-ear structures responsible for the initial stages of hearing. NIHL has always been associated with noisy work-places (e.g., factory machinery, construction tools, farming equipment). In more recent times, other threats to healthy hearing have included loud leisure-time activities involving, for example, sporting events, live amplified music, and recreational shooting. However, it is only within the past few decades that the general availability of personal music-players has made the risk of hearing damage seem more menacing.

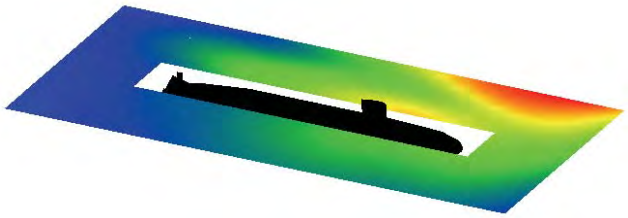
"Most certainly, the media have contributed to the fear that the recent rise in popularity of MP3 players and personal music players is causing more frequent hearing loss than ever before and at younger ages"

Recently, several studies have reported an increasing trend of NIHL in children and adolescents. For example, Chung *et al.* (2005) posted a web-based survey on the Music Television Video (MTV) web site to obtain general health information from the MTV generation including whether these individuals were aware that over-exposure to loud music could result in a hearing loss. The results from almost 10,000 completed surveys were somewhat disheartening in that hearing loss was ranked as a low priority relative to other health issues such as sexually transmitted diseases, alcohol/drug use, depression, smoking, nutrition and weight issues, and acne. Surprisingly, most respondents had experienced tinnitus (i.e., ringing in the ears or head) and hearing impairment after attending concerts and clubs. However, one hopeful finding of the study was that many adolescents and young adults indicated that they would wear hearing protection to avoid a lifelong hearing loss condition, if they were advised to do so by a medical professional.

Most certainly, the media have contributed to the fear that the recent rise in popularity of digital audio entertainment devices like MP3 players and personal music players is causing more frequent hearing loss than ever before and at younger ages than earlier models of portable music-playing devices such as transistor radios and personal cassette stereo players. Clearly, modern audio technology with its long-lasting lithium-ion batteries, internal gigabyte memory-storage capability, and snugly fitting insert earphones (e.g., earbuds) presents a genuine hearing hazard, the degree of which is related to both the level of noise as well as to the duration of the exposure.

Whether the expectation of a rise in hearing problems in children and adolescents due to portable media players is real or not is undergoing active debate at this time. While many parents, in particular, are concerned about the potential risk of hearing loss from the over-use of personal music-playing devices, cynics maintain that there are serious problems that include sampling errors in recent surveys like the one mentioned above and in opinion polls claiming digital audio players are causing greater hearing losses in our youths than they did in the past. In addition, normal aging eventually causes impaired hearing (i.e., presbycusis), and consequently the natural decrease in hearing sensitivity as people get older also needs to be factored into such surveys which often it is not. Whatever the outcome of this argument, there is no doubt that the popularity of such advances in audio technology has lowered the age at which children listen to portable music players. Thus, not only are millions of adults of all ages potentially at risk for developing recreational NIHL due to over-exposure to digital music players, but young children are too, especially if they are listening at high volumes for long periods of time.

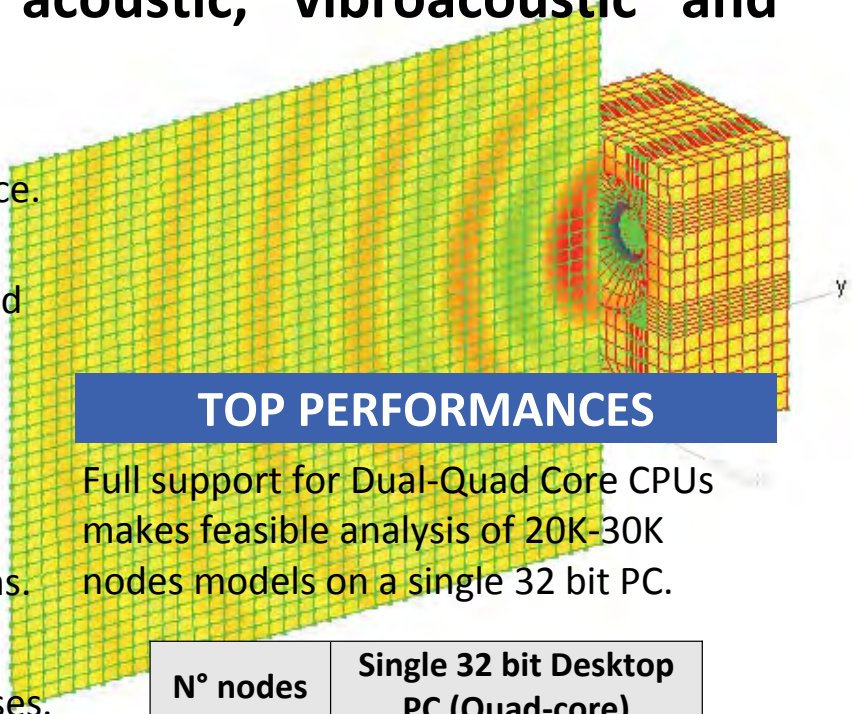
Scientists once thought that the pure energy of loud sounds caused forceful mechanical vibrations in the inner ear that directly damaged the receptor cells for hearing called hair cells, because of their fine hair-like projections. The microscopic hair cells located in the inner ear's fluid-filled, coiled cochlea are sensitive cells that convert acoustically induced vibratory energy into electrical signals that are interpreted by the brain as understandable sounds. It is likely that such mechanical trauma does tear hair cells apart with a one-time exposure to sudden, very intense sounds like those associated, for example, with an explosion. However, more recent research on habitual sound exposure has shown that more typical exposures to loud sounds gradually initiate the formation of harmful molecules inside the ear that eventually damage or destroy hair cells by building up toxic waste products. The destructive products are known as free oxygen radicals or reactive oxygen species. Such toxic molecules are formed after the cochlea's hair cells are stressed by noise-induced reductions in blood flow, excessive and deadly levels



VNoise

VNoise, the new generation Boundary Element software package for acoustic, vibroacoustic and aeroacoustic analyses.

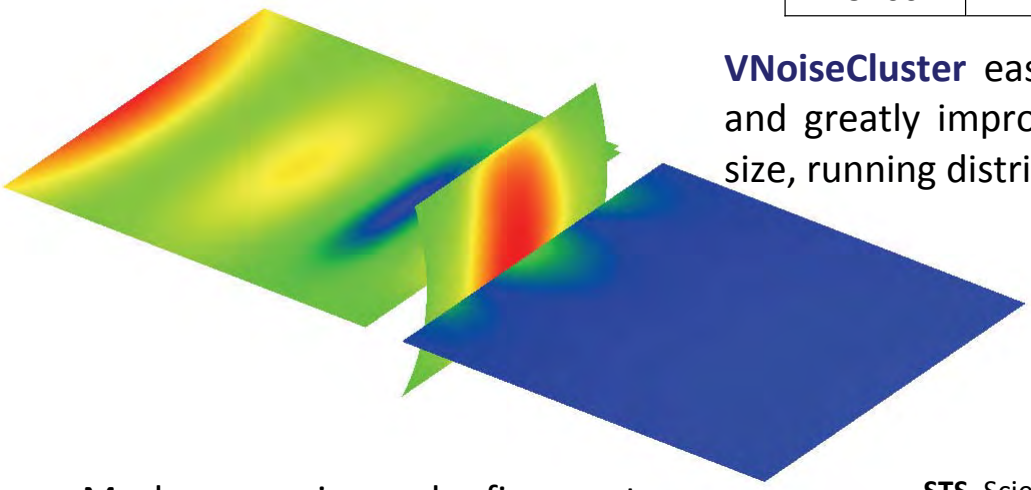
- Simple, full featured user interface.
- Unmatched modelling flexibility: direct and indirect BEM, multi and mixed domain approaches.
- Fully coupled structural acoustic analyses.
- Extremely fast iterative solver.
- Interface with FEM/CAE platforms.
- Full set of boundary conditions.
- Batch Files, multiload case analyses.
- Aeroacoustic radiation analysis with Ffowcs Williams Hawkings solver.



TOP PERFORMANCES

Full support for Dual-Quad Core CPUs makes feasible analysis of 20K-30K nodes models on a single 32 bit PC.

N° nodes	Single 32 bit Desktop PC (Quad-core)
2300	25 sec.
9000	130 sec.
19200	630 sec.



VNoiseCluster easily permit to further and greatly improve speed and model size, running distributed analyses with a standard PC network.

- Mesh coarsening and refinement.
- Postprocessing tools for evaluation of TL, sound-power, Intensity.
- Responsive technical support.

SCIENTIFIC TECHNICAL SOFTWARE

STS. Scientific and Technical Software
Via Dalmazia 30, 21100 Varese (VA), ITALY
Tel: (+39) 0332-333871
Fax: (+39) 0332-341113
http://www.sts-soft.com
info@sts-web.it

of cochlear neurotransmitters (e.g., glutamate), alterations in intracellular calcium balances, and other changes related to metabolic exhaustion. The free radicals injure a wide variety of essential structures (e.g., nuclear DNA, membranes, mitochondria) in the cochlea causing cell damage and cell death through several cell-death sequences including apoptosis and oncosis (Bohne *et al.*, 2007). Eventually, widespread cell death caused by noise over-exposure leads to NIHL.

Within the cochlea, different groups of hair cells are tuned to unique frequencies, which, for the healthy human ear, span a frequency range from 20-20,000 Hz (i.e., a measure of vibration rate per second). Typically, the high-frequency area of the cochlea is damaged initially by loud noises, which makes it more difficult to listen to the high-pitched voices of children and many women as well as to discern words that contain certain consonant sounds (e.g., 'ess' and 'ch'), particularly if they are spoken in the presence of background noise. Unfortunately, once damaged or decimated by unmanageable levels of toxic free radical molecules, hair cells cannot repair themselves or grow back thus causing a permanent hearing loss. Frequently, this type of NIHL is also accompanied by tinnitus.

The federal agency of the National Institutes of Health (NIH) that funds research into the causes, diagnosis, treatment, and prevention of NIHL, i.e., the National Institute on Deafness and Other Communication Disorders (NIDCD), estimates that about 10% of Americans between 20-69 years old (or 22 million Americans) already have suffered permanent damage to their hearing from exposure to excessive noises including those in the workplace, recreational settings, and at home. The NIDCD also speculates that some 30 million people are at risk for NIHL in these same settings. In fact, NIHL is the most common work-related disease. Earlier, Niskar *et al.* (2001) estimated from the database of the Third National Health and Nutrition Examination Survey (NHANES III) representing a national, population-based, cross-sectional survey that some 5.2 million 6-19 year olds (12.5%) have hearing loss directly related to noise exposure.

NIHL is a preventable hearing problem. By practicing good hearing health in everyday life, the hazards of being exposed to excessive noise can be avoided. You simply need to know that sounds above 85 decibels (dB sound pressure level or SPL) can damage the ear. Because of the occupational risk of NIHL, specific government standards regulate allowable noise exposures above this level, at least, in the workplace. Also, protective earplugs that fit snugly into the outer ear canal, special earmuffs that fit over the entire outer ear, or other hearing protective devices, which are usually available at pharmacies and hardware and sporting goods stores, should be worn when involved in a loud activity. Properly fit earplugs or earmuffs reduce sound by 15-30 dB. Further, if you suspect a NIHL, consult a physician, i.e., otolaryngologist or otologist/neurotologist, who specializes in diseases of the ear, or arrange for a hearing test by an audiologist. If you believe that you have grown used to loud noise, it probably has already damaged your ears. And, as stressed by the American Hearing Research Foundation (AHRF), to date, there is no approved treatment, i.e., no medication and no surgery to reverse a permanent hearing loss like NIHL. Not even a hearing aid can truly correct your hearing once it is damaged by noise.

However, several research groups have begun testing various chemicals for their safety and effectiveness in preventing or countering NIHL. Each of these candidate remedies for NIHL controls oxidative damage from free radicals either by directly blocking their creation or by removing free radicals from the cell before they damage critical intracellular structures. There is no doubt that a 'hearing pill' that could be taken in conjunction with a noisy event (e.g., before or after) would make a more amenable option than wearing hearing protection devices or limiting the time spent exposed to loud sounds. At present, three potentially otoprotective chemicals (i.e., D-methionine, ebselen, and N-acetylcysteine) are being tested in humans (e.g., Kopke *et al.*, 2007). All three, which have been shown to have excellent safety profiles in preliminary human studies, enhance the natural antioxidant, glutathione, which is found in hair cells and which battles chemical stress. Each of these agents can be simply dissolved in water or can be taken orally as pills. If these tests are successful and the United States Food and Drug Administration (FDA) approves the drugs, they will be the first pharmacologic products of their kind to combat NIHL. FDA approval, claim the developers of these drugs, likely means that an over-the-counter remedy for NIHL will be available within the next 5-10 years.

In the meantime, a number of professional organizations provide helpful information on the dangers of portable music players. For example, over the past several years, the American Speech-Language-Hearing Association (ASHA), an organization of hearing, speech, and language professionals, has conducted a consumer awareness campaign called 'Listen To Your Buds' that alerts individuals to the potential risk of hearing loss from the unsafe usage of personal audio devices. The NIDCD also has formed a coalition with the National Institute for Occupational Safety and Health (NIOSH) and more than 60 diverse national organizations [e.g., National Hearing Conservation Association (NHCA)] to conduct the WISE EARS!® campaign aimed at preventing NIHL over a life time. Also, academic institutions like the Oregon Health and Science University have partnered with public state-government agencies such as the Oregon Museum of Science and Industry to mount consumer crusades, in this case, the Dangerous Decibels® campaign, aimed at reducing the prevalence of NIHL and tinnitus through exhibits, educational outreach, and research. The Dangerous Decibels® program maintains that NIHL can be prevented through three highlighted messages: 'turn it down,' 'walk away,' and 'protect your ears.'

The underlying mechanisms of NIHL are still not fully understood, although one notion is that intense noise overstimulation leads to metabolic changes that compromise the cellular elements of the inner ear. For certain, over the past 100 years, the knowledge that loud noise may result in hearing loss has been well established. And, the phenomenon of NIHL has clearly been linked to recreational noise and

leisure-time activities. Although brief periods of exposure to amplified sound may be experienced with permanent hearing loss, the damage from exposure to those sound levels is cumulative. Thus, a slight hearing loss in childhood can eventually become a significant one in adulthood. The prevention of such hearing loss ideally begins with education targeting children, adolescents, and young adults. The heartening news about reaching this target audience is that according to the Chung *et al.* (2005) report discussed above, although young people appear to be unaware that loud noise may result in hearing loss, they seem to be willing to listen to advice concerning the use of hearing protection to avoid NIHL.**AT**

References for further reading

AHRF website, www.american-hearing.org/disorders/hearing/noise_induced.html (last viewed 09/03/2007)

ASHA website, www.listentoyourbuds.org (last viewed 09/03/2007)

Bohne, B., Harding, G. W., Lee, S. C. (**2007**). "Death pathways in noise-damaged outer hair cells," Hear. Res. **223**, 61–70.

Chung, J. H., Des Roches, C. M., Meunier, J., Eavey, R. D. (**2005**). "Evaluation of noise-induced hearing loss in young people using a web-based survey technique," Pediatrics **115**, 861–867.

Dangerous Decibels website, www.dangerousdecibels.org/ (last viewed 09/03/2007)

Kopke, R. D., Jackson, R. L., Coleman, J. K., Liu, J., Bielefeld, E. C., Balough, B. J. (**2007**). "NAC for noise: from the bench top to the clinic," Hear. Res. **226**, 114–125.

NIDCD websites, www.nidcd.nih.gov/health/hearing/noise.asp (last viewed 09/03/2007) and www.nidcd.nih.gov/health/hearing/wiseears.asp (last viewed 09/03/2007)

NIOSH website, www.cdc.gov/niosh/topics/noise/faq/faq.html (last viewed 09/03/2007)

Niskar, A. S., Kieszak, S. M., Holmes, A. E., Esteban, E., Rubin, C., Brody, D. J. (**2001**). "Estimated prevalence of noise-induced hearing threshold shifts among children 6 to 19 years of age: The Third National Health and Nutrition Examination Survey, 1988-1994, United States," Pediatrics **108**, 40–43.

Additional Resources:

American Academy of Audiology (AAA) website, www.audiology.org (last viewed 09/03/2007)

American Academy of Otolaryngology—Head & Neck Surgery (AAOHNS) Inc website, www.entnet.org (last viewed 09/03/2007)

American Tinnitus Association (ATA) website, www.ata.org (last viewed 09/03/2007)

National Hearing Conservation Association (NHCA) website, www.hearingconservation.org (last viewed 09/03/2007)

Noise Pollution Clearinghouse website, www.nonoise.org (last viewed 09/03/2007)

Brenda L. Lonsbury-Martin is a professor of otolaryngology at Loma Linda University and a senior research scientist in the Veterans Affairs Loma Linda Healthcare System. She received her BA in psychology and zoology from the University of Victoria and her MS and Ph.D. in medical psychology and cell biology from the Oregon Health and Science University. After postdoctoral fellowships in psychobiology at the University of California (Irvine) and physiology and biophysics at the University of Washington, she served as an assistant professor at the latter institution. In 1984, she was appointed as an associate professor at Baylor College of Medicine, and from 1991–2001 she served as the Chandler Professor of Otolaryngology at the University of Miami. From 2001–2003, she was a professor at the University of Colorado Health Sciences Center and then she served as the Chief of Research and Science for the American Speech-Language-Hearing Association (ASHA) until 2006. Her laboratory has conducted physiological research on the auditory system in the areas of otoacoustic emissions and noise-induced hearing loss for over 25 years. She is currently a member of the Technical Committee on Psychological and Physiological Acoustics of the Acoustical Society of America (ASA) and also serves on the ASA's Publication Policy and Public Relations Committees. She is an associate editor (peripheral physiological acoustics) for the *Journal of the Acoustical Society of America* (JASA) and serves on the Advisory Committee for the *Journal of the Acoustical Society of America—Express Letters* (JASA-EL). Dr. Lonsbury-Martin is currently on the editorial board of *Hearing Research*, and is a member of the National Tinnitus Research Consortium, and ASHA's Advisory Committee on Evidence-Based Practice and the American Academy of Otolaryngology—Head and Neck Surgery's Committee on Hearing and Balance. She is an elected member of the Board of Directors of the American Auditory Society and an ASA fellow.

Glen K. Martin, Ph.D., is a senior research scientist for the Veterans Affairs Loma Linda Healthcare System and a professor in the Department of Otolaryngology– Head & Neck Surgery at the Loma Linda University School of Medicine. Dr Martin's research interests include the early detection of hearing loss using otoacoustic emissions, mechanisms of noise and drug-induced hearing loss, the role of the cochlear efferent system in protecting the ear from noise and ototoxic-drug damage, and cochlear plasticity. Dr Martin's laboratory has been developing and refining procedures to measure otoacoustic emissions to evaluate, screen, and monitor the health of the hearing portion of the inner ear over the past 20 years. He is a member of the American Auditory Society, the Association for Research in Otolaryngology, and the Society for Neuroscience. Dr. Martin received his BS degree in psychology and microbiology at the University of Washington, and his MS and PhD degrees in neuroscience and physiology from the Oregon Health and Science University. After completing postdoctoral fellowships at the University of California/Irvine and the University of Washington, he was a faculty member at Baylor College of Medicine, the University of Miami, and the University of Colorado Health Sciences Center.