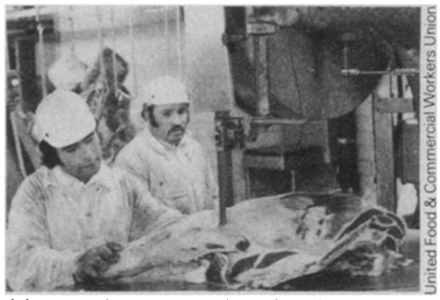
Occupational noise — the subtle pollutant

An insidious hazard threatens at least 8% of all U.S. workers



Meat-cutting rooms where band saws are used for boning can exceed 90 dB.

By JANET RALOFF

The first of two parts

What's the most widespread occupational hazard facing American workers? Noise, according to most experts. Not only does loud noise threaten hearing, but new studies also implicate it in the development of high blood pressure, ulcers and neurological disorders. Noise can irritate, affect one's memory and potentiate the ability of certain drugs to impair hearing. And statistically, occupationally induced hearing loss has been correlated with a substantial number of the work-related accidents that occur each year. Changes in federal noise-control standards, which go into effect this year, should protect a greater share of the nation's workforce. But that protection, while better, still falls far short of 100 percent.

According to the Environmental Protection Agency, 75 decibels (dB) is the maximum sound intensity to which most adult humans can be exposed for eight hours a day throughout a 40-year career without any risk of hearing loss. Yet the Occupational Safety and Health Administration estimated last year that 53 percent of the nation's roughly 15 million production workers are exposed to workplace noise at 80 dB or higher — and at least 5.1 million work in environments where the sound levels exceed the legally permissible eight-hour time-weighted exposure limit of 90 dB set by OSHA.

"It's unfortunate that damage to hearing doesn't hurt," audiologist Alan Feldman noted at a noise-control conference earlier this year, because if it did, workers would be better aware of the risks they confronted. As it is, noise-induced injury usually is gradual, progressive, painless — and *permanent*. More important, without submitting to special audiological tests, it's unlikely that a victim would ever become aware of hearing impairment in its early stages.

The first phase of hearing loss is a noise-induced "permanent threshold shift" affecting the perception of sound intensity. In practical terms, it means that the decibel intensity — or degree of loudness — necessary to make sounds audible will have increased permanently for at least some audible frequencies.

It has also been noted that hearing impairment seems to sensitize ears to further injury: As the ear is damaged, the sound-pressure (or decibel-level assault) necessary to produce a given degree of damage will decrease. If assault continues, even sound amplification from hearing aids becomes useless. The sensory hair cells, whose stimulation contributes to our perception of sound, will die; unable to regenerate, these hair cells represent an irretrievable loss of hearing at the pitch to which they are sensitive.

Hair cells sensitive to the highest frequencies are generally the first lost from noise. Intensity and duration of noise determines damage severity.

Because of the resonance characteristics of the external auditory canal, high-frequency sound will be amplified — at 4 kHz "by as much as 18 dB," according to Clifton Springs, N.Y.-otolaryngologist Stephen Falk. What's more, there is greater redundancy among the hair cells capable of sensing low-frequency sound. A report he authored for the National Institute of Environmental Health Sciences says destruction of 20 percent of the hair cells in the cochlear apex — where hair cells sensitive to low-frequency sound reside — may occur "with no change in hearing sensitivity," whereas the same damage to the basal portion of the cochlea, sensitive to high frequencies, will cause roughly a 40 dB hearing loss (or threshold shift).

It's because the frequencies associated with speech are comparatively low (roughly 500 hertz [Hz] to 2 kilohertz [kHz]), that loss of hair cells sensitive to the higher-frequency end of the auditory spectrum — 4 kHz to 20 kHz — may go largely unnoticed. With continued assault by noise or other ototoxic (hearing impairing) agents, however, death of hair cells will progress toward the cochlear apex, eventually deadening reception of even speech-related pitches.

While exposure to loud noises is hardly new, major compensation claims for noise-induced injury are. And it is perhaps this financial aspect of the problem that has had the biggest impact on encouraging American industry to work with federal regulators on a national hearing-conservation policy.

Marc Kramer, a New York audiologist who specializes in forensic matters for Noise and Hearing Consultants of America, notes that harbor workers have

Major provisions of OSHA's hearing-conservation amendment

Firms covered by OSHA regulations (farms and construction sites are exempted) must:

- Survey noisy shops by February 1982 to establish the decibel-level exposures to which employees in specific work stations would be exposed without hearing protection.
- Develop a hearing-conservation program to cover any employee exposed to continuing noise at or above 85 dB — the noise level of urban, rush-hour traffic.
- Give each worker in the noise-conservation program a baseline audiogram by August 22,1982, to establish the individual's hearing at entry to the program.
- Retest annually all employees working in an 85 dB or higher environment. Compare audiograms to determine if there has been any measurable hearing loss — such as a 20 dB "significant threshold shift" (STS) at any tested pitch.
- Offer hearing protectors to workers exposed to 85 dB noise, and require issuance of protectors to all in 90 dB or higher environments.
- Train workers in use and care of hearing protectors and ensure they are worn by all who need them.
- Refit hearing protectors on any persons incurring an STS and retrain them in their protector's use.
- Notify any worker in writing within 21 days of a significant change in hearing. If necessary, send individual to outside specialist — at employer's expense — for further testing.
- Maintain up-to-date training program on noise for workers in the hearing-conservation program, and require their participation at least annually.
- Keep records on noise-exposure levels in the workplace, keep audiometric evaluations of workers for as long as they remain employed — and make all records available to workers, former workers, their representatives, and the Labor Department.

been able to win an average compensation of almost $1,500 per decibel of established hearing loss (over the speech-related frequencies) in excess of 25 dBs. As a class, production workers are generally exposed to the loudest occupational environments, and therefore develop the most hearing loss. But there can be exceptions, Kramer noted, like the dental hygienist who brought a $1 million suit in New York against the manufacturer of equipment used in her office. Recalling that "she had what I would call a real clear case of noise-induced hearing loss," Kramer says she easily settled out of court for $30,000.

But that's just the tip of the iceberg in claims-compensation potential. Says Kramer, "It's conceivable that the magnitude of the problem might be close to the cost of running a hearing conservation program" — something OSHA expects will average $53 per affected worker annually. Kramer adds that some firms are anticipating that thousands of their employees will eventually file claims as these workers become more aware of both the noise-induced injury they have sustained and the degree to which employers can be held accountable. As a result, establishing to what extent workplace exposure has brought about an employee's total measured disability is now in the employer's financial interest. And the new amendment to OSHA's hearing-conservation rules — which goes into effect this year — should help considerably in establishing occupationally induced damage (see box p. 347).

Employees entering the workplace with pre-existing noise-induced injury will be at greater risk to further injury than most other entering workers. Among the most important sources of nonoccupational noise exposures are military duty—where one can encounter gunfire and mortar shelling in the 140 dB to 185 dB range, hunting gun or recreational-handgun fire, snowmobiles and rock bands. To some extent, pre-employment injury from such sources will be picked up among new workers in the baseline audiograms that employers are now required to issue workers exposed to loud noise. If these individuals develop further injury later on, their baseline audiograms may limit the employer's liability for their total disability. What employers cannot yet protect against is the worker's "self-abuse"—such as listening to loud music — while employed, but off the job.

Even among workers exposed to sound levels no higher than the permissible exposure limit (8 hours at 90 dB or its risk equivalent, see table), however, some hearing loss will occur. The National Institute of Occupational Safety and Health estimates that 29 percent of the workers exposed to no more than the federal standard will suffer permanent hearing loss.

Many noise researchers had hoped OSHA's recent amendment to the noise regulations would lower the permissible exposure limit to 85 dB for just that reason. But even an 85 dB standard would not protect everyone, notes John Erdreich of the NIOSH noise-research office in Cincinnati. In a study, soon to be published by his office, workers in the papermaking industry were shown to have developed "significant hearing losses when compared to our control population," he says — at exposures of only 85 dB.

Audiologists attending the American Speech-Language-Hearing Association's hearing-conservation symposium in March had additional criticisms of OSHA's hearing-conservation amendment. John Fletcher, chairman of the psychology department at the University of Missouri-Rolla and a pioneer in studies of occupationally induced hearing loss, points out a major problem — enticing workers to use hearing protection correctly. "Most people are allergic to pressure," he notes jokingly. So when earplugs begin to feel uncomfortable, workers frequently resort to makeshift gestures that subvert a protector's effectiveness. Fletcher noted many workers snip off the tip, which fits deepest into the ear, to relieve irritating pressure. When earmuffs become warm, users sometimes poke holes in them for ventilation, or loosen them so much that they flop as the workers walk; they should hug snugly. In short, he says, "nothing is workerproof."

In fact, an unpublished study just completed by NIOSH has evaluated hearing protectors as they are used. "We've gone into factories, taken people off the line, had them leave their earplugs as they were, and then measured the attenuation of their threshold [to sound] with the earplugs — and without. And what we find," Erdreich says, "is that workers may be getting half or less than half the protection that the manufacturers specify should be available" — in one case, "a factor of 100 less." The result did not surprise him because of all the variability witnessed in earplug use: "You'll see guys taking earplugs and inserting them sideways," he says, "or maybe halfway in instead of all the way."

Kramer has problems with the federal rule's flexibility in defining the significant hearing loss for which injured workers may claim compensation: What is significant? "Actually, the issue is open right now," says Alice Suter, a senior scientist at OSHA with supervision over the analysis and development of standards for her agency's hearing conservation amendment. "We're saying employers can use any reasonable definition," Suter says, "and when in doubt, we will use 20 dB at any [single] test frequency."

Kramer notes, however, that some employers and audiologists have chosen to average the threshold shifts registered at 2 kHz, 3 kHz and 4 kHz, or at 3 kHz, 4 kHz and 6 kHz when figuring hearing loss. The problem comes, he points out, when you have someone with a 20 dB shift at a single frequency, such as 3 kHz; their speech comprehension could be truly impaired by a loss of the sibilant — "s" and "sh" sounding — consonants. While OSHA's in-house measuring policy would detect the impairment, Kramer says, the averaging policy would not.

OSHA's noise exposure limits

Noise (dB_A)*	Permissible exposure (hours and minutes)
85	16 h
87	12 h 6 m
90	8 h
93	5 h 18 m
96	3 h 30 m
99	2 h 18 m
102	1 h 30 m
105	1 h
108	40 m
111	26 m
114	17 m
115	15 m
118	10 m
121	6.6 m
124	4 m
127	3 m
130	1 m

Federal Register data

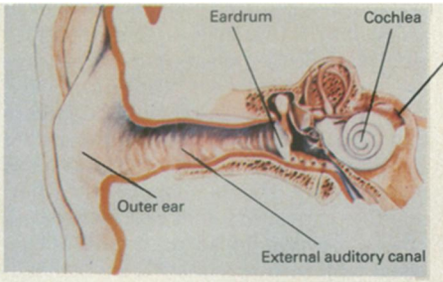
Daily occupational exposure limits for workers with unprotected ears. Exposures above or below the 90 dB limit have been "time weighted" to give what OSHA believes are equivalent risks to a 90 dB eight-hour exposure. *A-weighted dB scale accounts for frequency sensitivity of the human ear.

"Marc Kramer's right," Suter told SCIENCE NEWS. Some prefer averaging because it's less sensitive to audiometric and technician error, she explains, but adds that if you define as significant anything greater than a 10 dB shift, then by averaging "you could have more than a 20 dB shift at one frequency and it wouldn't show up — even 25 dB wouldn't necessarily show up."

That is due to change. A final, uniform definition — based on public hearings the agency held several weeks ago — should be out "in a couple of months," Suter says. What it will be like is anyone's guess: Suter said, "We are considering averaging techniques along with a variety of others."

Maurice Miller, president of the Lawrence, N.Y.-based Hearing Conservation Consultants, Ltd. raised concern about whether many unsuspecting workers might be at increased risk of hearing impairment from the synergistic effects of noise and drugs. A number of studies involving laboratory animals have shown that certain ototoxic drugs will multiply the damaging effect of noise on hearing. Studies using the aminoglycoside antibiotic kanamycin, for instance, caused permanent damage in doses at which neither the noise or drug alone would have been hazardous. Other work suggests that in some cases the temporary hearing loss associated with certain ototoxic drugs (and normally lasting only as long as the drug stays in the body) could become permanent after coincident exposure to high-level noise.

Much concern over a possible drug-noise synergism stems from anecdotal evidence. Miller noted, for example, the

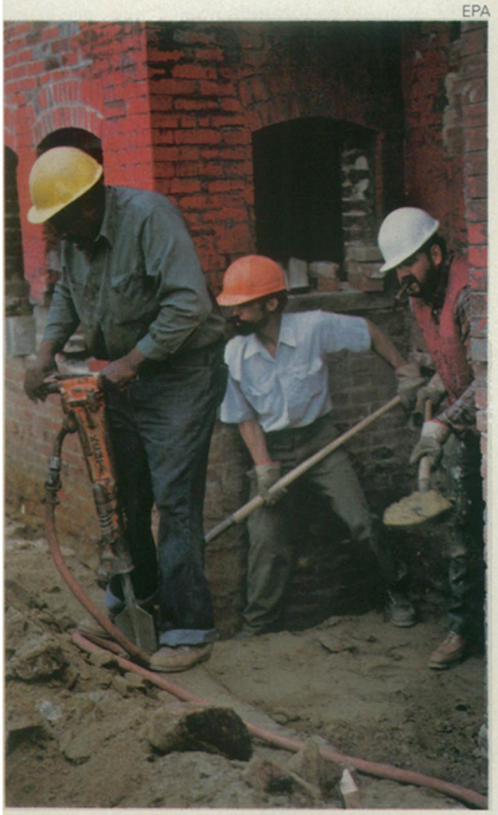


After Bilsom Int'l.

Sounds go through the ear's structures by vibration. Upon reaching the spiral-shaped cochlea, they will bend some of its sensory hair cells. This action stimulates nerves at the hair cells' roots, which in turn send signals to the brain.

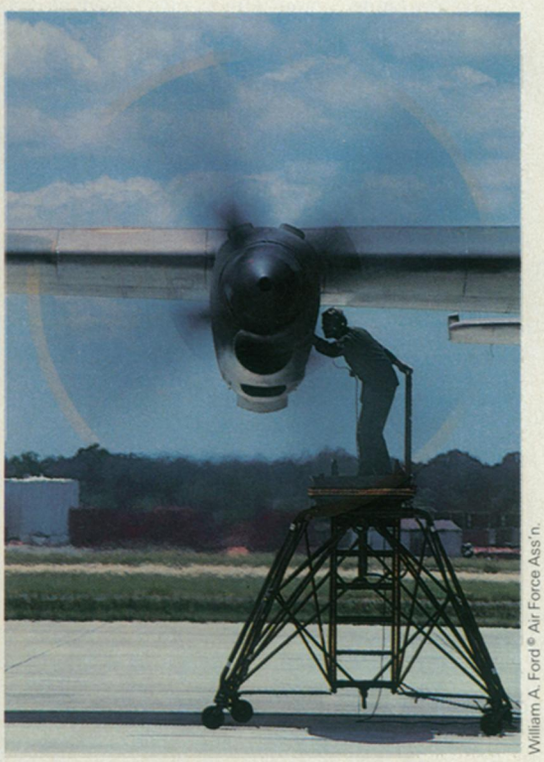
Mine Safety and Health Admin.

Coal-seam worker manning the "continuous miner" is exposed to between 95 & 104 dB_A continuous noise. By age 50, half of all coal miners have impaired hearing.



EPA

Construction workers may encounter sound levels from jackhammers or pneumatic chippers of 100 dB_A.



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Mechanics service C-130 (above) and A-10 (left). Depending on engines' power level and where workers stand, aircraft mechanics may be exposed to between 88 and 120 dB_A.

William A. Ford © Air Force Assn.

"Although we enjoy a high standard of living, we pay for it in part with the noise our remarkable technological society creates."

Charles Elkins,
May 1978, NATION'S CITIES
(then director of EPA's noise programs)

Ototoxic agents

Agent	Ototoxicity: Permanent	Temporary	Suspected	augmented* by
Aminoglycoside antibiotics				
streptomycin	✓			loop diuretics (LD)
kanamycin	✓			LD, noise
neomycin	✓			LD, noise
gentamicin	✓			LD
tobramycin	✓			LD
amikacin	✓			LD
netilmicin	✓			LD
sisomicin	✓			LD
Loop diuretics				
ethacrynic acid	?	✓	}	viomycin, capreomycin, polymyxin-B, *cis*-platinum
furosemide	?	✓	}	
bumetanide	?	✓	}	
Anti-inflammatory and analgesic drugs				
acetylsalicylic acid (aspirin)		✓		slightly by noise
indomethacin		✓		
other salicylates		✓		
Local anesthetics & ear drops				
procaine hydrochloride (2%)		✓		
hexylcaine hydrochloride (1% & 5%)			✓	
cocaine (10%)	?	✓		
lidocaine (0.5%)		✓		
polymyxin-B (as ear drops)	✓			LD
chloramphenicol (as ear drops)	✓			
erythromycin (as ear drops)	?			
Cancer treatment drugs				
nitrogen mustard	✓			
6-aminonicotinamide	✓			
cis-platinum	✓			LD
Other drugs				
intravenous erythromycin (at high doses)		✓		
minocycline		✓		
Heavy metals				
arsenic			✓	
cadmium			✓	
lead			✓	
methyl mercury			✓	
zinc			✓	
gold			✓	
manganese			✓	
Chemicals				
iodoacetate (ingested)	✓			

*These agents can or might impair hearing when used alone. *There is growing concern that many may also prove to have a synergistic (or "augmented") effect when coupled with exposure to noise.*

List adapted from chapters 7-9, Pharmacology of Hearing, (John Wiley & Sons, NY 1981) and conversations with pharmacologist-ototoxicologist Robert Brummett, Kresge Hearing Research Laboratory, Portland, Ore.

suspicion held by several research audiologists that occasional cases of childhood deafness might be traceable to the antibiotic treatment (for infections) of premature infants who had been kept in relatively noisy hospital incubators.

Miller also expressed concern that aspirin, when taken in high doses—30 or more daily — might potentiate the effects of noise. Aspirin will cause demonstrable hearing loss at such doses for as long as treatment lasts, Miller notes. And aspirin is occasionally prescribed at such levels to counter arthritic symptoms. However, in this case Miller's concern appears to be unfounded. The latest studies suggest that even after exposure to loud noise, full hearing will return upon suspension of aspirin treatment at high-dose levels.

Joseph Hawkins of the University of Michigan, a renowned leader in ototoxicology, is one who tends to discount the likelihood of seeing a synergism beween drugs or chemicals and noise, except in isolated circumstances. Conceding that the idea of synergisms "has not been completely ruled out," Hawkins says that studies in his laboratory at the University of Michigan's Kresge Hearing Research Institute showed kanamycin to be an anomaly, as drugs go, with regard to its reaction on the ear when combined with noise.

Kanamycin works on the part of the cochlea sensitive to high-frequency sounds. Using guinea pigs, Hawkins was able to get damage beyond what would have been expected from the drug alone when he exposed the animal to 8 kHz. Exposures of kanamycin-drugged animals to lower frequencies reduced the damage seen until at 500 Hz there was no damage beyond what kanamycin would have produced alone.

Based on work in his laboratory, he concludes that "the idea that there's a potentiating effect appears to be quite clearly not established yet — except in the specific instance where you have a high-frequency noise and a drug working on the high-frequency part of the cochlea." But in fact all aminoglycoside antibiotics — not just kanamycin — work on the high-frequency part of the cochlea, according to Jack Vernon, director of the University of Oregon Medical School's Tinnitis (ringing in the ears) Clinic.

Probably the most confounding factor in the whole issue is that while the list of known or suspected ototoxic agents is long (see box), the number that have been tested coincidentally with noise is meager. As a result, it's not yet known whether the effects of one drug should be extrapolated to represent those of a whole class of similar drugs. However, because technically the jury is still out on this issue, most researchers recommend playing it safe by shunning exposure to high-level sound while using or in contact with known ototoxic agents.

What may ultimately prove most controversial, however, is OSHA's regulation of impulse noise—from the hammering of a nail into a two-by-four or rivet into a steel plate, to the pulsation of a drop forge or pneumatic chipper. "OSHA's conviction," according to The Federal Register, is that short, intense high-decibel noise "is as harmful to hearing as continuous noise of equivalent sound energy." Since permissible exposure limits expressly developed to cover impulse noise have not yet been written, the conservation amendment requires factoring impulse noise into the continuous-noise levels of a work environment.

However, "most of our experiments," Roger Hamernik at the University of Texas-Dallas told SCIENCE NEWS, "indicate that equal-energy considerations don't seem to apply to impulse noise," and "are therefore probably not adequate" for extrapolating the risk of injury from data that have involved only continuous-noise exposures. Results of animal research conducted at the university's Callier Center, and reported by Hamernik at a conference in Oslo, Norway, this month, demonstrate that high-decibel impulse noise is indeed more hazardous than lower-level continuous noise of equivalent total energy.

The finding might have been anticipated, Hamernik says, since anecdotal evidence shows "people who work in environments—both military and industrial—with a lot of impulsive kinds of sounds get the most hearing loss the quickest." He says "hearing loss [from impulse noise] seems to accumulate more rapidly — in the course of five years, say, instead of 10" for continuous noise. More controversial, however, in his assertion that, based on his experiments, he finds that for impulse noise, "peak levels are a better indicator of the hazard than any energy consideration." If this is confirmed, it will mean many workers exposed to impulse noise are not being protected adequately by OSHA's rules, which equate the hazard of impulse noise to that of continuous noise.

Erdreich also points out that researchers haven't yet established whether sound level meters exist to make reliable measurements of the impact-noise energy of many industrial processes, especially when impulses are superimposed on a varying background of continuous noise. As a result, dose-response studies of human populations exposed to impulse noise — and applicable to setting special impulse-noise standards — may be a minimum of three or more years away, he says.

Finally, not to be overlooked is the potential for noise to wreak nonauditory injury, most notably high blood pressure. Research on these subtle, though seemingly pervasive, side effects of noise illustrate even more graphically the hidden threat in treating noise as just an irritant. Noise is a hazard to health, and industrial workers are far from the only population at risk. □

Next: The body's response to noise.