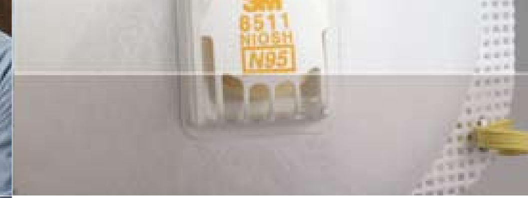

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JobHealth Highlights

Technical Information for Occupational Health and Safety Professionals

Recommended Changes to OSHA Noise Exposure Dose Calculation

Ted K. Madison, M.A., CCC-A

Ted Madison is a certified Audiologist and a Regulatory Affairs Specialist with the 3M Occupational Health and Environmental Safety Division. He is also Past-President of the National Hearing Conservation Association (NHCA).

3M Occupational Health and Environmental Safety Division has joined with other hearing protector manufacturers in expressing support for a proposal by the International Safety Equipment Association (ISEA) to change OSHA regulation 29 CFR 1910.95 on Occupational Noise Exposure. In a formal request delivered on January 26, 2007, ISEA petitioned OSHA Administrator Ed Foulke to lower the 8-hour Time Weighted Average (TWA) permissible exposure limit (PEL) for occupational noise from 90 dBA to 85 dBA and to adopt a 3 dB exchange rate for calculating noise dose as a function of exposure time and level. The rationale for implementing these changes is clearly stated in a position paper written for ISEA by widely respected hearing conservation expert, Alice Suter, Ph.D., who authored much of the existing OSHA noise regulation more than 20 years ago. In her paper, Dr. Suter describes the significant reduction in work-related noise-induced hearing loss that is likely to occur with a more protective PEL and noise dose calculation paradigm. The first half of that paper, which described the scientific evidence supporting the 85 dBA PEL, was re-printed in the previous issue of Job Health Highlights, with the permission of ISEA. In this issue we present the second half of Dr. Suter's paper featuring a discussion of the basis for using a 3 dB exchange rate and the implications of doing so.

II. Select the 3-dBA Exchange Rate (ER)

1. The Exchange Rate Defined

The exchange rate has been known by several names: the "time-intensity trading rule," the "doubling rule," and the "trading relation," but since OSHA's hearing conservation amendment was promulgated, the tradeoff between duration and intensity has been called the exchange rate, abbreviated here as ER. It is the increase in noise exposure level that can be allowed for every halving of duration, with presumably the same hazard resulting to hearing.

2. Origins of the 5-dBA Exchange Rate

In 1965 the Committee on Hearing and Bioacoustics (CHABA) developed sets of octave- and one-third-octave band curves for predicting equally hazardous noise exposures for bands of noise and pure tones for various levels and durations of noise (Kryter et al., 1966). The members determined that the relationship between level and duration was curvilinear, with a relatively shallow function for long, moderate-level noise bursts, and a much steeper function for high-level, short duration bursts interspersed with quiet periods. The authors then predicted the amount of hearing loss that would occur from various exposures to continuous and intermittent noise on the basis of hearing threshold measurements in industrial populations for the long-duration continuous exposures, and on the basis of temporary threshold shift (TTS) data for short-burst continuous and intermittent noise exposures. The CHABA criteria were dependent upon three postulates:

The CHABA criteria were dependent upon three postulates:

1. TTS_2* is a consistent measure of the effects of a single day's exposure to noise.
2. All exposures that produce a given TTS_2 will be equally hazardous (the "equal temporary effect" theory).
3. NIPTS** produced after many years of habitual exposure, 8 hours per day, is about the same as the TTS_2 produced in normal ears by an 8-hour exposure to the same noise.

* TTS_2 is the temporary threshold shift in hearing that occurs approximately 2 minutes after exposure cessation.

** NIPTS is noise-induced permanent threshold shift.

The 3-dBA exchange rate will increase the number of employess that exceed the PEL

Two years later, Botsford published a simplification of the CHABA criteria based on typical manufacturing noises, which converted the octave-band curves to equally-hazardous A-weighted levels (Botsford, 1967). This method assumed that there would be interruptions of equal length and spacing throughout the work day, during which any shifts in workers' hearing would presumably return to normal. In that same year an "Intersociety Committee" published another set of curves, again assuming uniform off-times, which, the members maintained, could be approximated by the simple rule that for each halving of duration the noise level could be increased by 5 dB (Intersociety Committee, 1967). In 1970 the Committee revised its criteria replacing the curves with a table showing permissible exposure levels (starting at 90 dBA) as a function of duration and number of occurrences per day, again with varying exchange rates depending on noise levels and frequency of occurrence (Intersociety Committee, 1970). For continuous noise with durations less than 8 hours, the 5-dBA ER was recommended. This simplification of several complex sets of curves, based upon questionable assumptions, found its way into the Department of Labor's noise standard in 1969 (Dept. Labor, 1969).

There are several reasons why the CHABA criteria's postulates have been disputed (see Suter, 1992; ACGIH, 2000). First, the assumption that TTS is a valid predictor of permanent hearing loss (postulates #1 and 3) has not been validated (Shaw, 1985; Ward, 1980). Next, the assumption that all exposures that produce a given TTS_2 will be equally hazardous has proven erroneous. In fact, Ward found that high-frequency intermittent exposures producing the same amount of TTS as continuous noise always require longer periods of recovery (Ward, 1970). Several other researchers found delayed recovery from moderate levels of noise if the exposures are of relatively long duration (Mills et al., 1970; Melnick, 1974; Melnick and Maves, 1974). Thus TTS may not be allowed to recover before the next exposure, compounding the risk of permanent threshold shift (PTS).

Another assumption implicit in the CHABA criteria and its subsequent modifications is that the sound level during intermittencies will be low enough to permit full recovery from TTS. However, the TTS curves were generated during laboratory exposures, where the sound levels during the quiet periods bear little resemblance to the factory or other noisy workplaces. The sound level thought to be the maximum level that will fail to produce any threshold shift in hearing has been termed "effective quiet." Research over the years has indicated that effective quiet is frequency dependent, showing a range of levels from about 65 dB for the 2000 and 4000 Hz frequencies, to 70 dB for the 500 and 1000 Hz frequencies (see Suter, 1992; Mills, 1982). A recent examination of the issue concludes that A-weighted sounds of 75 dB do not produce TTS, whereas sound levels of 80 dBA do, so the author postulates a level of 78 dBA as the upper limit of effective quiet (Lawton, 2001).

It is fair to say that the origins and development of the 5-dB ER do not support its validity. The CHABA assumptions have not been validated. Also, Botsford's simplification was, in fact, an oversimplification of the original curves showing varying exchange rates for various types of noise exposures, since Botsford's method assumed evenly spaced intermittencies without regard to noise level or duration, and the realities of working conditions. Finally, the assumption of effective quiet during the intermittencies may be valid for the laboratory setting but not for industry, especially in factories or enclosed spaces where reflection and reverberation keep noise levels high.

3. Support for the 3-dBA Exchange Rate

The origins of the 3-dBA ER cannot be pinpointed to a certain time, but it is clear that the study of Burns and Robinson (1970) added to its credibility, and it has been increasingly adopted by national and international organizations. Data from animal experiments have confirmed its validity for single exposures of various levels within an 8-hour day (Ward and Nelson, 1971; Ward and Turner, 1982; Ward et al., 1983). There is evidence, however, that intermittency can be beneficial, especially in the laboratory (Bohne and Pearse, 1982; Ward and Turner, 1982; Ward et al., 1982; Bohne et al., 1985 and 1987; Clark et al., 1987). But these benefits are likely to be small or nonexistent in the industrial environment, where sound levels during intermittencies are higher and where interruptions are not evenly spaced.

3-dBA exchange rate is so widespread that it is used exclusively today

In addition to the study of Burns and Robinson, several other field studies have produced data pertaining to the issue of the exchange rate (see Passchier-Vermeer, 1971 and 1973; Shaw, 1985). Some field data from intermittent exposures in outdoor occupations, such as forestry and mining, show less hearing loss than would be predicted according to the 3-dBA ER (Holmgren et al., 1971; Johansson, 1973; INRS, 1978), although these findings have not been supported by two NIOSH studies of intermittently exposed outdoor workers (1976 and 1982). If there is a beneficial effect of intermittency in certain occupations, it is further supported by the laboratory evidence that intermittencies, when sufficiently quiet, produce a savings over continuous noise exposures.

It is important to note, however, that any ameliorative effect of intermittency does not support the use of the 5-dBA ER. When Ward, for example, noted that some industrial studies showed less PTS from intermittent noise exposure than would be predicted by the 3-dBA ER, he did not favor selection of the 5-dBA ER as a compromise because it would allow single exposures at excessively high levels. In his opinion, this compromise would be "futile and perhaps even dangerous." (Ward, 1970)

If indeed there were an ameliorative effect of intermittency for outdoor exposures, the logical way to address this effect would be to use an adjustment to the PEL, not to use a different exchange rate. Ideally, the amount of this adjustment would be determined by the temporal pattern of the noise and the levels of quiet between noise bursts, with larger adjustments allowed for intermittent periods that meet the definition of effective quiet and are long enough to permit recovery from TTS. A conservative approach would be to allow a 2-dBA increase to the PEL for outdoor occupations, since this is the savings that Ward and Turner (1982) found for an on-time of 50%. In the practical world, however, this kind of adjustment would be difficult to implement and even more difficult to enforce.

4. Precedent for the 3-dBA Exchange Rate

Acceptance of the 3-dBA ER is so widespread that it is used almost exclusively today. In the U.S., the EPA adopted it in the early 1970s for the development of its damage-risk criteria (EPA, 1973), and the identification of safe levels of noise exposure for the prevention of any hearing loss (EPA, 1974). The Department of Defense (DoD) has endorsed the 3-dBA ER, along with the 85-dBA PEL, and recommends it for all DoD components (other branches of the military) (DoD, 2004). The Air Force and Army have used 3-dBA for several years, and the Navy is finally in the process of converting from the 4-dBA to the 3-dBA ER (Hutchison, 2006).

In its earlier criteria document on noise, NIOSH considered several rules for the relationship between noise level and duration, especially with regard to intermittent noise, but was unable to make a change in the 5-dBA ER until more information became available (NIOSH, 1972). Subsequently, in its more recent criteria document, the Agency concluded that the 3-dBA ER is the method most firmly supported by the scientific evidence, whether or not an adjustment is made to the PEL for certain intermittent exposures (NIOSH, 1998).

The ACGIH adopted the 3-dBA ER in 1994. In addition to several of the justifications cited above, the ACGIH gives the following reasons (ACGIH, 2000):

- The "awkward all-or-nothing" limit of 115 dBA could be eliminated by extending the 3-dBA ER to higher levels, thus allowing short bursts of noise such as an aircraft flyover or a passing siren, which could exceed the current limit.

- The 3-dBA ER is actually more lenient than the 5-dBA ER for exposure durations longer than 8 hours, assuming the same starting point (such as a PEL of 85 dBA). For example, the allowable level for 16 hours would be 82 dBA rather than 80 dBA. The committee concluded that extending the 3-dBA rule to a 24-hour exposure of 80 dBA would be reasonably safe.
- The original CHABA criteria showed that the benefit of intermittency varied with audiometric frequency, and the higher frequencies required a smaller ER than the lower frequencies to produce equal amounts of TTS. Therefore the ACGIH determined that the 3-dBA ER is more protective of the audiometric frequencies above 2000 Hz, which are important for understanding speech.

The 3-dBA ER has been used in Europe at least since the time of the 1971 ISO standard, R1999 (ISO, 1971), which was subsequently revised as ISO R1999.2 (ISO, 1990). The 3-dBA ER, often called the "equal-energy rule" in Europe, was incorporated into the 1986 and 2003 directives issued by the European Communities, which instructed the European "Member States" to do likewise.

In addition to the European nations, most other nations around the world have adopted the 3-dBA ER. Table 2 shows the PEL and ER used by various nations, along with the date of their standards or regulations when available. Most of this information is current within the last few years, but the reader is cautioned that some may have been recently revised.

Workers continue to lose their hearing due to the inadequacy of current regulations

Table 2. Permissible exposure limits and exchange rates used by various nations.

Nation, date	PEL (8-hour average) dBA	Exchange rate dBA	Level dBA engineering controls	Level dBA audio tests, and other HC practices	Comments
Argentina, 2003	85	3	85	85	
Australia, 2000	85	3	85	85	Note (1)
Brazil, 1992	85	5	85		
Canada, 1991	87	3	87	84	Note (2)
Chile, 2000	85	3			
China, 1985	85	3	85		
Colombia, 1990	85	5			
EU, 2003	87	3	85	85	Note (3)
				80	Note (4)
Finland, 1982	85	3	85		
France, 1990	85	3		85	
Germany, 1990	85	3	90	85	Note (5)
Hungary	85	3	90		
India, 1989	90				Note (6)
Israel, 1984	85	5			
Italy, 1990	85	3	90	85	
Mexico, 2001	85	3	90	80	
Netherlands, 1987	80	3	85		Note (7)
New Zealand, 1995	85	3	85	85	
Norway, 1982	85	3		80	
Spain, 1989	85	3	90	80	
Sweden, 1992	85	3	85	85	
United Kingdom, 1989	85	3	90	85	
United States, 1983	90	5	90	85	Note (8)
Uruguay, 1988	85	3	85	85	
Venezuela	85	3			

Note (1) Each of the Australian states and territories has its own legislation for noise, but all have now adopted the 8-hour PEL of 85 dBA and the 3-dBA ER.

Note (2) Despite the existence of a Canadian national standard, there is some variation among the standards of the individual Canadian provinces: Ontario, Quebec, and New Brunswick use 90 dBA with a 5-dBA ER; Alberta, Nova Scotia, and Newfoundland use 85 dBA with a 5-dBA ER; and British Columbia uses 85 dBA with a 3-dB ER. Most require engineering controls to the level of the PEL. Manitoba requires certain hearing conservation practices above 80 dBA, hearing protectors and training on request above 85 dBA, and engineering controls above 90 dBA.

Note (3) The European Union (Directive 2003/10/EC) puts forward three exposure values: an exposure limit value of 87 dBA; an "upper action" level of 85 dBA; and a "lower action" level of 80 dBA, all using the 3-dBA ER. The attenuation of hearing protectors may be taken into account when assessing the exposure limit value, but not for requirements driven by the upper and lower action values. At no time shall employees' noise exposures exceed the exposure limit value. When exposures exceed the upper action level, the employer must implement a program of noise reduction, taking into account technology and availability of control measures.

Note (4) EU cont.: Hearing protectors must be made available when exposures exceed the lower action value of 80 dBA. Hearing protectors must be used by workers whose exposures equal or exceed the upper action value of 85 dBA. Audiometric testing must be available to workers whose exposures exceed the upper action value, and when noise measurements indicate a risk to health, these measures must be available at the lower action value.

Note (5) The German standard (UVV Larm-1990) states that it is not possible to give a precise limit for the elimination of hearing hazard and the risk of other health impairments from noise. Therefore the employer is obliged to reduce the noise level as far as possible, taking technical progress and the availability of control measures into account.

Note (6) India: This is a recommendation, not a regulation.

Note (7) The Netherlands' noise legislation requires engineering noise control at 85 dBA "unless this cannot be reasonably demanded." Hearing protection must be provided above 80 dBA and workers are required to wear it at levels above 90 dBA.

Note (8) These levels apply to the OSHA noise standard, covering workers in general industry and maritime. The U.S. military services require standards that are more stringent, with the Department of Defense as a whole using the 85-dBA PEL and the 3-dBA exchange rate. The Air Force and Army have similar requirements and the Navy is about to adopt the 3-dB ER.

Sources for Table 2:

Jorge P. Arenas, Institute of Acoustics, Universidad Austral de Chile, Valdivia, Chile. Paper presented at the 129th meeting of the Acoustical Society of America, 1995. Also via personal communication, Feb. 2005 for updated information on noise standards of Latin American nations.

Pamela Gunn, WorkSafe Division of the Department of Consumer and Employment Protection, Perth, Western Australia (personal communication, March 2005).

Tony F.W. Embleton, I-INCE Publication 97-1: Final Report - Technical Assessment of Upper Limits on Noise in the Workplace. Approved by the Board of Directors of I-INCE on 1997.08.23 and published in Noise/News International, 5, 203-216, 1997.

Christine Harrison, Worker Compensation Board, British Columbia (personal communication, March 2005).

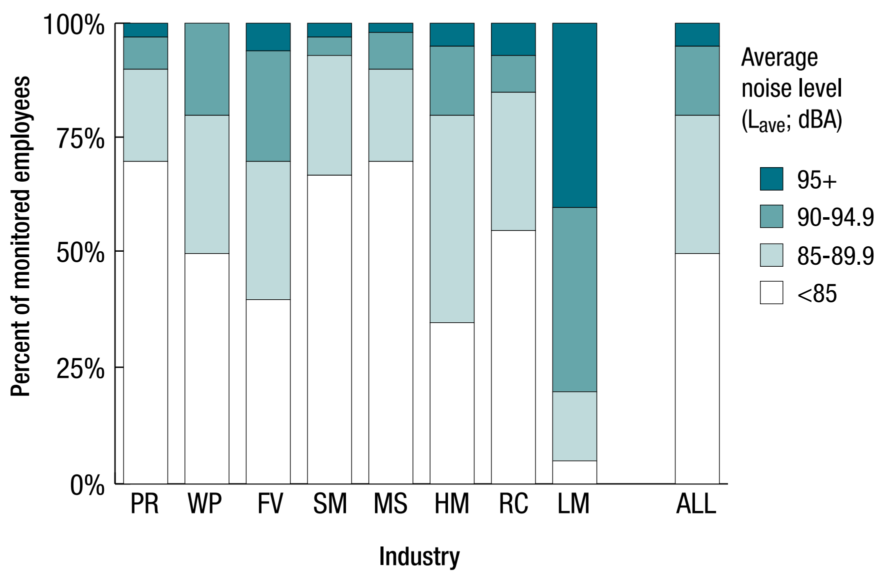
ILO, Noise Regulations and Standards, CIS data base, International Labour Office, Geneva, Switzerland (summaries), 1994.

Published standards of various nations.

There is no doubt that using the 3-dBA ER will increase the number of employees that exceed the PEL and who need the benefits of a hearing conservation program (HCP). Recently, Seixas and his co-workers published a large study of construction workers with various types of noise exposures from continuous (e.g. operating engineers) to highly variable (e.g. carpenters and iron workers) (Seixas et al., 2005). The authors found that the work-day exposure level calculated with the 3-dBA ER was an average of 5.7 dBA higher than when calculated according to the 5-dBA ER. A smaller study of variously exposed workers showed a 6.6 dBA difference and also a 2.7-fold increase in the number of workers needing to be enrolled in an HCP when using the 3-dBA ER (Sriwattanatamma and Bryssee, 2000).

In a large study of workers in eight different industries, Daniell and his colleagues found that using the 3-dB ER would produce a 1.5- to 3-fold increase in the percentage of workers overexposed (Daniell et al., 2006). They found that 50% of the workers equaled or exceeded 85 dBA when using the 5-dB ER, but 74% did using 3-dBA. With regard to the 90-dBA PEL, the percentage was 42% using 3 dBA and only 14% using 5 dBA. Figures 1 and 2, from Daniell et al., (2006), give a clear indication of how the two ERs affect the percentages of employees exposed in a variety of industries to ranges of average noise levels from less than 85 dBA to more than 100 dBA. One can see that it is not only the employees exposed between 85-90 dBA who are affected, but all ranges, even those exposed to average levels above 100 dBA.

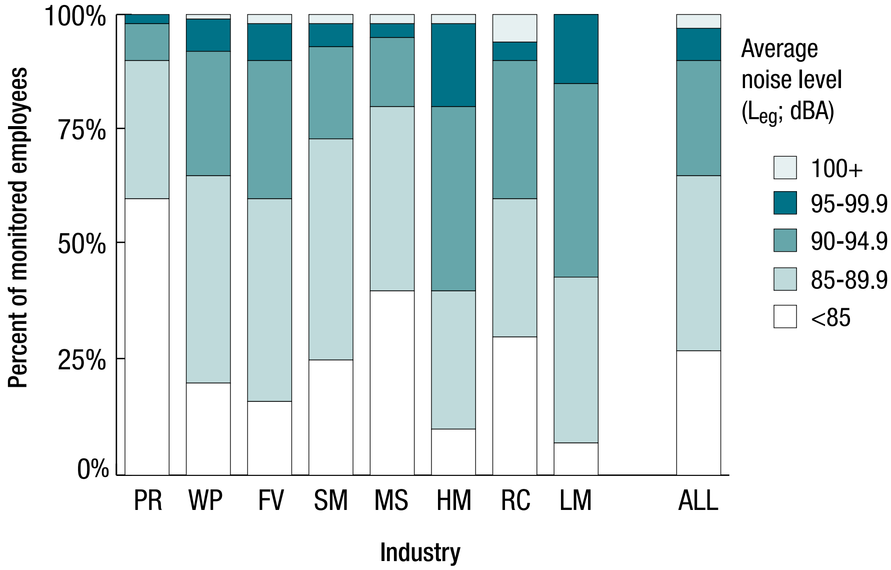
Fig. 1. Full-shift personal noise exposure by industry. Results derived using the 5-dBA ER. (From Daniell et al., 2006)



Abbreviations:
Lave or Leq= full-shift time-weighted average sound pressure level using OSHA (5-dBA ER) or NIOSH (3-dBA ER) parameters, respectively.

PR, printing; WP, wood products mfg; FV, fruit/vegetable mfg; SM, sheet metal mfg; MS, machine shops; HM, heavy gauge metal mfg; RC, road construction; LM, lumber milling.

Fig. 2. Full-shift personal noise exposure by industry. Results derived using the 3-dBA ER. (From Daniell et al., 2006)



Abbreviations:
Lave or Leq= full-shift time-weighted average sound pressure level using OSHA (5-dBA ER) or NIOSH (3-dBA ER) parameters, respectively.

PR, printing; WP, wood products mfg; FV, fruit/vegetable mfg; SM, sheet metal mfg; MS, machine shops; HM, heavy gauge metal mfg; RC, road construction; LM, lumber milling.

There are two reasons for viewing these statistics with alarm. One is, of course, pragmatic, and that is the need for greater efforts and resources to be allocated to HCPs. The other is that we have traditionally underestimated the harm caused by workers' noise exposures, and therefore allowed too many workers to be overexposed. This may help to explain why workers continue to lose their hearing, despite some 35 years since the time of OSHA's first noise regulation, and 25 years since the promulgation of the hearing conservation amendment.

IV. Enforcement and Compliance

Two other salient reasons why workers continues to lose their hearing are the lack of compliance with existing regulations and the preference for hearing conservation programs over engineering noise control.

It is no secret that HCPs are often inadequate or even absent in noisy industries. In a study of worker compensation claims for hearing loss in mainly small and medium-sized companies in the State of Washington, Daniell and his colleagues found dramatic increases in claims between 1984 and 1998 (Daniell et al., 2002). While many of these claims were undoubtedly due to reporting artifacts, the authors found clinically significant hearing losses in all age brackets over 36 years, which caused them to question the effectiveness of ongoing HCPs. In a larger, follow-up study, they documented the efforts of company managers to provide HCPs to employees exposed to average levels of 85 dBA and above (Daniell et al., 2006). Most of these companies had conducted noise measurements, but most kept no records. The use of noise control was low in all industries, although 51% reported that they had made some kind of change to reduce noise, but only 10% reported that they had measured the noise levels afterward. All of the companies provided hearing protection devices (HPDs) but only 34% had policies requiring their use. Training in HPD fitting was provided by 63% of the companies and 74% conducted annual audiometric testing. When employees exhibited an OSHA standard threshold shift (STS) in hearing, only 62% provided written notification and a mere 37% provided retraining.

Daniell et al. (2002) found that in companies where relatively few workers were overexposed, the use of HPDs among them was not as consistent as in companies where a larger proportion were overexposed. They also found, as have other investigators (e.g. Neitzel and Seixas, 2005) that workers with higher noise exposures were more likely to wear HPDs regularly, and companies with more noise-exposed workers were likely to have HCPs that were more complete (Daniell et al., 2006). This caused the authors to state ironically, that: "workers with the greatest risk for OHL [occupational hearing loss] may be those employed at companies where a moderate or low percentage of workers are over-exposed to noise but use of protection is low, rather than at companies where noise is most prevalent and protector use is higher." (Daniell et al., 2006 p. 349)

A large study of an occupational hearing loss surveillance system in Michigan showed that some 46% of individuals with noise-induced hearing loss did not receive regular audiometric testing (Reilly et al., 1998). Lack of adequate HCPs was particularly characteristic of companies with less than 100 employees, although 30-47% of the larger companies still had not provided audiometric testing in the 1990s.

Enforcement may not provide adequate incentives at this time, however, as Daniell and his colleagues (2006) found that most of the studied companies had been inspected by the Washington State OSHA but only 9% had received a citation on noise or hearing conservation. Surprisingly, current HCP completeness or the use of HPDs appeared to be unrelated to the occurrence of past inspections or citations, causing the authors to conclude: "These findings suggest the regulatory priority given to personal protection and hearing conservation programs needs to be re-evaluated. There is a need either for increased regulatory enforcement or consultation to make this strategy effective or for greater emphasis on reducing levels of noise." (Daniell et al., 2006 p. 349)

An important first step is to unify the action level and PEL at 85 dBA

Unfortunately, there is not much incentive for companies in the U.S. to control noise exposure through engineering means. With the relaxed enforcement strategy published in 1983 and still in effect today, OSHA allows TWAs to exceed 100 dBA in some circumstances (OSHA, 1983). However, the Agency should realize that incomplete and ineffective HCPs cannot be substituted for engineering controls.

OSHA needs to undertake a serious study of economically and technically feasible strategies for controlling noise, including lower noise levels for new plants and processes, "buy quiet" programs, the labeling of noisy machinery, and various incentives or rewards for quieter workplaces. The Agency also needs to undertake a serious examination of its enforcement strategies with regard to HCPs to ensure that employers' programs are effective in preventing hearing loss.

In the mean time, workers continue to lose their hearing due to the inadequacy of current regulations and their enforcement, combined with either a lack of information or a lack of will (or a combination of the two) on the part of employers. An important first step in addressing these problems would be to unify the action level and PEL at 85 dBA and adopt a 3-dBA exchange rate. The near universal acceptance of these recommendations by virtually all other agencies and departments within our government, as well as much of the rest of the world, renders our current occupational regulations unjustifiable and increasingly unconscionable.

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