Atelier : Protecteurs individuels : quelle est leur atténuation réelle ?

Practical noise attenuation of hearing protectors according to noise directive 2003/10/EC

Rauno Pääkkönen
Finnish Institute of Occupational Health
P.O. Box 486
FIN-33101 Tampere
Finland
E-mail : rauno.paakkonen@ttl.fi

Summary
In our measurement of standard ear muffs and plugs a noise attenuation of 10-24 dB was achieved. In practical circumstances the noise attenuation of hearing protection is usually less than claimed in laboratory tests. Many factors contribute to this, such as individual differences (morphology, beard, hair, etc.) and skill in applying the protector. Secondly, simultaneous use of other protective devices such as eyeglasses, respiratory devices or helmets may reduce the attenuation of hearing protection. At the workplace level, very simple evaluation models are required or attenuation evaluation requirements at workplaces are ignored.

Résumé
Nos mesures de performance des protections auditives classiques (casques et bouchons d'oreille) ont montré que ces dernières offraient une atténuation du bruit allant de 10 à 24 dB. En pratique, l'atténuation produite par les protections auditives est généralement inférieure à celle revendiquée par les tests en laboratoires. De nombreux facteurs contribuent à cette différence, comme les caractéristiques individuelles (morphologie, barbe, cheveux, etc.), et l'habileté à mettre en place les protections auditives. En outre, l'utilisation simultanée d'autres équipements de protection comme des lunettes, des masques respiratoires, ou des casques, peut diminuer l'efficacité des protections auditives. Il est nécessaire de recourir à des modèles d'évaluation très simples sur les lieux de travail car les normes d'évaluation concernant l'atténuation du bruit au travail sont ignorées lorsqu'elles sont trop complexes.

The implementation of the new noise directive 2003/10/EC sets a limit value that must not be exceeded when hearing protective devices (HPD) are used. The simplest way to compare the exposure limit values is to measure the noise exposure outside the hearing protector and then evaluate the exposure inside it by using one of the methods given in EN458. Since the attenuations provided by the manufacturers are based on laboratory results, they tend to overestimate the practical attenuation. In addition, the use of several protectors may decrease the attenuation of HPDs. Thus there are situations in which this exposure inside the HPD must be measured, for example, in a military environment, the wood-working industry or the metal industry.

According to the noise directive, when noise exposure exceeds 80 dB, hearing protection devices (HPD) can be used and employers must provide HPDs for workers upon request. When noise exposure of 85 dB is exceeded, workers must use HPDs and the employer must make every effort to ensure the wearing of hearing protectors. The limit value is 87 dB expressed as a daily/weekly exposure. Depending on the efficiency of hearing protectors, this exposure limit is exceeded with ambient noise exposure of 95-125 dB. In Finland the labour protection authorities require expert evaluation of hearing protectors when noise exposure of 95 dB is exceeded. Double protection cannot normally be used because no attenuation data is available for this solution. If double protection is used, daily exposure can be as high as 130 dB, but beyond this limit the possible solutions are the shortening of exposure time and/or the use of technical noise control solutions.

In laboratory conditions the HPDs attenuate noise 20-40 dB when measured as a SNR-index. However, there are many indications that practical noise reduction in working conditions is significantly less, such as 0-30 dB (Berger 1986, 1988, Casali & Berger 1996, Pääkkönen 2000a-d). In addition, working, eating, speaking, and other facial movements reduce the noise attenuation of hearing protectors (Pääkkönen 2000a and 2000d). In a Finnish study, average noise attenuation was 17 dB in industrial workplaces (Pekkarinen 1989). However, particularly during short inspections, HPDs are not always used, and these short periods without use of protectors can reduce effective attenuation of HPDs significantly, as Figure 1 shows. If a person is exposed to high-level noise without hearing protectors, even for five minutes, the efficient attenuation of hearing protectors is seriously reduced.

The noise attenuation of HPDs in practice is also reduced by communication, application difficulties — especially with ear plugs, wearing eyeglasses or headgear — protector maintenance problems, beards and hair. In the laboratory, the attenuation of HPDs is determined by the standard series of EN 352. Practical noise reduction can be made in audiometric chambers by subjective hearing threshold (REAT = real ear at threshold) or at real work (MIRE = microphone in real ear) (Berger 1986, Pääkkönen 2000c). According to a standard EN 458, some properties and evaluation models are defined for workplace use (EN 1993). The noise attenuation of HPDs against low-frequency noise and impulse noise can be difficult to evaluate.

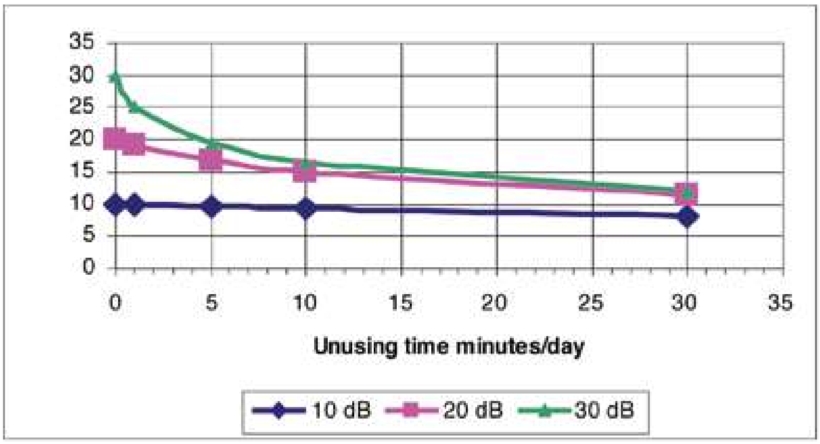

Fig. 1 : The deterioration of the attenuation of hearing protectors if they are not used all the time The purpose of this presentation is to evaluate the practical issues of hearing protection, especially regarding the problems for evaluation due to the noise directive

Materials and methods

The data were collected on workplace visits where there was discussion on the real attenuation of hearing protectors. In the MIRE method, a miniature microphone (<5x5 mm) was fixed to the end of the earplug and inserted into the ear canal. When an earmuff was used the microphone was located at the entrance of the ear canal. The microphone signal was transferred through thin insulated wires (diameter less than 0,1 mm) to the recording device. A second microphone was located outside the HPD to measure the ambient noise level. The recording system consisted of a measurement amplifier and tape-recorder (Sony TCD D7-8) (7). In addition, a logging noise dose meter CEL-460 was also used. The logged noise profiles were analysed by a computer program, and the tape-recorded signals were analysed by a sound analyser (B & K 2260). The sound level analyser was also used directly in field conditions.

The earplug attenuation was determined by the TR method (TR = transmission reduction) ; in other words, the SPL in the ear canal with an earplug was subtracted from the SPL measured outside the earplug. The ear amplification (TFOE – transmission function of the open ear) of the SPL difference between the SPL in the ear canal without the earplug and the SPL outside the ear was calculated. From the measurement results it was also possible to determine the insertion loss (IL) by summing TR and TFOE :

$$IL = TR + TFOE \qquad (1)$$

Results

Table 1 shows examples of noise attenuation measurements in an industrial workplace. The noise attenuation varied from 10-30 dB. In jet engine testing the average noise exposure over the test period was 130 dB and the measured noise level inside hearing protectors was 100-107 dB (attenuation 23-30 dB), which indicates an allowed daily exposure duration of less than 15 minutes. In a cellulose factory the average noise attenuation of hearing protectors was 18 dB, which is significantly less than is usually claimed (SNR 25-30 dB). We have also previously measured that if there is oral communication or if the test subject is eating, then the noise attenuation against usual industrial noise is reduced by about 5 dB.

There are work tasks in which communication noise directed inside a headset can be too loud or workers are exposed to loud music directly into their ear canal. The quality of communication can be vitally important, for example, when transportation safety is evaluated. Among jet engine testing crew the attenuation of helmets was 23-30 dB, but this attenuation was reduced due to communication noise exposure. In addition, the background noise inside the helmet was elevated by 20 dB (from 70 dB to 90 dB) when the communications system was activated.

At a power plant the noise exposure was 95 dB, while under the hearing protector it was 65-75 dB, depending on the protector type. In the worst case, protective eye glasses cancelled out the attenuation and in the best case they did not have any effect on the attenuation (Figure 2). Therefore, the selection of eyeglasses has a very important influence on noise exposure. In particular, the insertion of ear plugs is a critical factor for noise attenuation, and noise attenuation against low-frequency noise is difficult to achieve. This can be seen in Figures 1 and 2. In some cases the use of eyeglasses can destroy the attenuation of ear muffs. In our examples the noise attenuation was reduced by 0-22 dB. The worst cases were those in which the noise content was of low frequency and the eyeglasses did not fit well between the skin and the cushion of the earmuff (Figure 1). With middle frequency noise in the power plant, noise attenuation was better, and minimal noise reductions could not be observed, although the effect of eyeglasses could be notified in the attenuation values (Figure 2).

Discussion

In our measurements of usual ear muffs and plugs a noise attenuation of 10-24 dB was achieved. In practice the noise attenuation of hearing protection was usually less than claimed in laboratory tests. Many factors

	Work	Protection	Noise exposure LAeq, dB	Noise inside a protector LAeq, dB	Attenuation dB
Metal factory	Sand blasting	Ear plug	96 inside a hood	86 at ear canal	10
Metal factory	Welding, grinding, sawing	Ear muff	98	84	14
Metal factory	Needle scaler	Ear muff	109	85	24
Cellulose factory	Inspection tasks, n=20	Ear plug and muff	98	80	18
Cellulose factory, Barking drum	Inspection	Ear muff	102	88	14
Repair shop	Jet engine testing	Ear plug and muff	130	100-107	23-30 special protection
				Variation	**10-30**

Table 1 : Examples of noise exposure inside and outside the protector from industrial noise

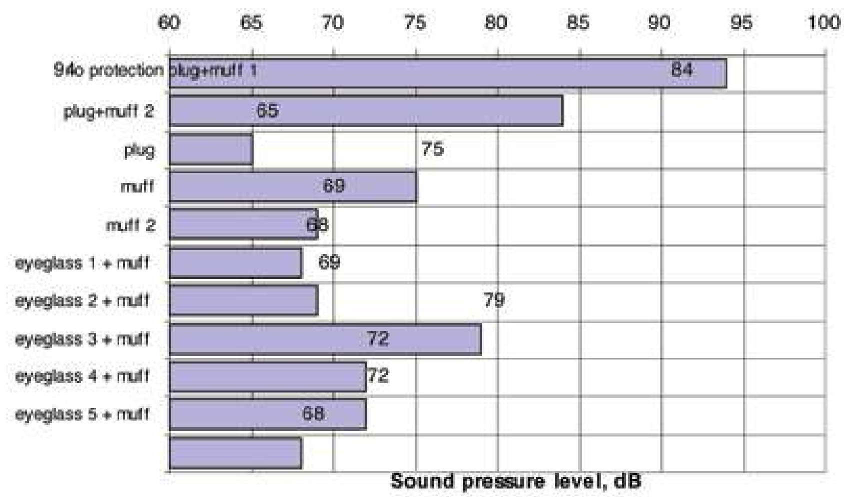

Fig. 2 : Noise attenuation of hearing protectors and combination of hearing protectors and protective eyeglasses against low-frequency noise of a barking drum at a cellulose factory

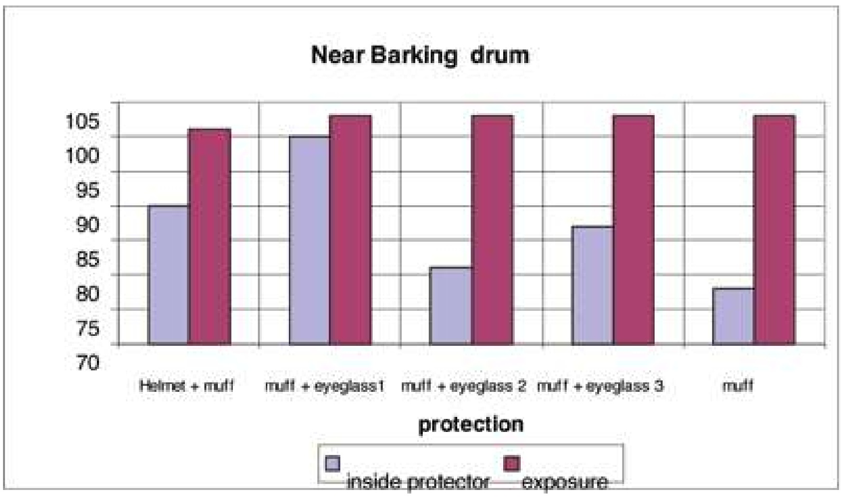

Fig. 3 : Noise attenuation of hearing protectors and combination of hearing protectors and protective eyeglasses against middle frequency power plant noise

contribute to this. First, individual differences (morphology, beard, hair, etc.) and skills to insert the protector vary significantly. Secondly, simultaneous use of other protective devices such as eyeglasses, respiratory devices or helmets may reduce the attenuation of hearing protection.

MIRE measurements are quite sensitive to errors. The miniature microphone can be inserted into the ear canal in such a way that the sound input of the microphone is blocked, which results in an overestimation of the noise attenuation. This cannot be controlled visually when the opening of the ear canal is blocked by the ear plug. This can be avoided by careful installation and on-line monitoring of the signal before the start of recording. The protector attenuation can also be momentarily diminished when the subject is talking, moving or making facial or jaw movements during measurement.

When measurements and evaluation are made at the entrance of the ear canal it is much easier to check.

Reduction of noise exposure is a key issue in the implementation of the noise directive. For example, in jet engine testing (Table 1), noise exposure over a short period of time (5 minutes/day) is 100-107 dB, even while using noise protection devices. This means that the daily noise exposure is about 87 dB. This means that no additional noise exposure should occur during that day. If there is a delay with engine testing, the only way to continue is to substitute a worker, which can increase a risk of operational safety of that machine. Therefore, an extremely sophisticated method of evaluation is needed for this work. In the abovementioned cases in Table 1 there is also an urgent need to develop new technical noise control methods.

When hearing protection evaluation was conducted for the implementation of the noise directive limit value (87 dB), our tests showed that the exposing noise value could be more than 100 dB for a general wide-frequency noise spectrum. When the noise is low-frequency or the user has not inserted the ear plug properly, the noise level of exposure can be even less — down to as low as 95 dB, as pointed out by Finnish labour protection authorities. Since measurements and evaluations are associated with significant uncertainty, emphasis should be placed on the technical means of reducing noise exposure. However, for critical conditions workplaces should seek expert help. These are very simple guidelines that workplaces require when conducting their evaluation. Standard EN 458 gives good guidance to evaluate the noise attenuation of hearing protectors. It also considers frequency and impulse responses. However, it relies strongly on laboratory attenuation values that are not achieved, as described in previous discussion. Therefore, a safety coefficient should be used. In addition, the validity of the methods is low if the workers cannot choose between several protectors, because of the variation in the morphology of the face. Still, the parallel use of other protection devices may reduce attenuation. Therefore practical factors and safety culture have an influence on real noise attenuation, which must also be evaluated.

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