

Radiography of HPD

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The market for hearing protection involves several entities who play various roles. From the local audiologist to thousands of employees on a multinational level, each one tries to prove that their product is the best.

From the simple earplug made of expandable foam that's remained unchanged for close to 40 years, to customized hearing protection achieved with the latest manufacturing technologies, the choice is indeed vast. The price range also varies widely, from ten cents for a basic disposable product to over a hundred euros for a product that can be used for many years.

Using the HearingProTech database, we shall try to get a better idea about the various products available.

Protection against noise
E-126.1



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2 The HPD market

According to a survey of Synamap, the segment for ear muffs mountable on helmets has enormously lost its value: firstly, the volume of these products is decreasing, and secondly, the average prices have fallen sharply due to the high imports of budget products from Asia. Customized earplugs have seen a positive growth, although the French market remains small in comparison to others such as the Benelux Union, for example.

According to the same survey, the losses in noise sources in conventional areas, due to relocations and corporate restructuring, have so far been offset by sectors that were not yet equipped. The potential for users to be equipped remains difficult to assess since the number of people exposed to noise is underestimated, mainly because the consequences of noise exposure are difficult to assess at a given time 'T'. Customized earplugs are substitutes for all other hearing protectors where, along with the price, comfort and design remain the most important factors. Due to their relatively high cost, employers are mainly directed toward these products for their most skilled and most stable employees.

3 The HPD database

The HearingProTech database at the time of radiography records 460 personal hearing protection devices. The products contained in this database are passive protectors; they do not have electronic systems for noise reduction.

Despite the care taken in updating the data, it is possible that data has changed in the meantime or that errors and inaccuracies exist. We do not claim any responsibility and therefore cannot guarantee the up-to-date nature, correctness or completeness of the information provided.

We request that you notify us of any inconsistency.

4 Classification

The HPDs (hearing protection devices) have been classified into five types.

Categories of hearing protectors	Number of hearing protectors present in the HPD database
Earplugs to be molded	43
Canal caps	19
Preformed earplugs	31
Customized earplugs	263
Ear muffs	104

Table 1: Distribution of the HPD database by category

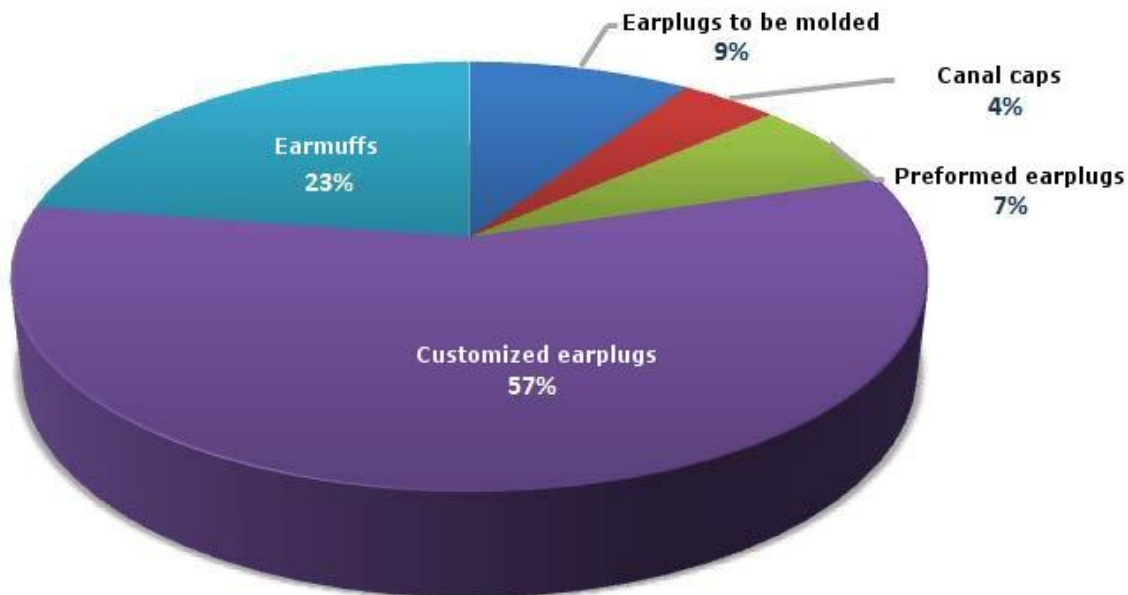


Figure 1: Distribution of HPD in percentage

Types of hearing protectors	Number of suppliers
Earplugs to be molded	6
Canal caps	4
Preformed earplugs	9
Customized earplugs	27
Ear muffs	5

Table 2: Number of manufacturers by category of hearing protector (list of manufacturers by type in the appendix)

The market for standard products is retained today by a few global players, mainly North America (see appendix). While that of customized products requiring proximity with users is much more fragmented, the majority of manufacturers of customized hearing protectors analyzed being European, these products are still less developed on the North American continent.

5 Attenuation

5.1 The attenuation index

Each patron has a specific impairment, e.g., 26 decibels.

This is a weighted average of the attenuation values by frequency expressed as SNR (Single Number Rating) in Europe and NRR (Noise Reduction Rating) in North America. These are global indications of attenuation. Here we shall use the index used in Europe, the SNR.

How is the attenuation of a hearing protector measured in Europe?

To be marketed as personal protective equipment (PPE), a hearing protector must meet the requirements of the following standards according to its type:

- EN 352-1: for ear muffs
- EN 352-2: for earplugs

These European standards have been developed by CEN (European Committee for Standardization) as per the European Directive on personal protective equipment (PPE).

Test methods for verifying the characteristics of the hearing protector are described in EN 13819-1 for physical testing and EN 13819-2 for noise tests. Tests are carried out by a laboratory approved and authorized by the Ministry of Labor, Employment and Health, which will deliver to manufacturers a "CE" certificate for hearing protectors that have passed the tests successfully.

The attenuation of the hearing protector is measured according to the specifications of EN 13819-2 in the central frequencies of 1/3-octave band (63Hz, 125Hz, 250Hz, 500Hz, 1KHz, 2KHz, 4KHz et 8KHz).

The tests are carried out on 10 to 16 experienced and trained subjects.

An average of the attenuation is calculated for each frequency. This average is subtracted from the standard deviation to obtain the APV (Assumed Protection Value) that provides information on the minimum attenuation of the hearing protector for a given frequency.

Averages are then established: H, M, and L corresponding to the average of the attenuation at high (H), medium (M) and low (L) frequencies. The SNR value is the weighted average attenuation on all frequencies.

Frequencies in Hz	63	125	250	500	1000	2000	4000	8000
Average attenuation (dB)	21.5	25.2	23.9	26.1	27.8	26.2	23.5	32.8
Standard deviation (dB)	3.2	5.8	4.3	3.6	4	4.2	3.4	6.6
APV (dB)	18.3	19.4	19.6	22.5	23.8	22	20.1	26.2
H (dB)	22	M (dB)	22	L (dB)	21	SNR (dB)	24	

Table 3: Display of attenuation values of HPD, according to EN352-1/EN352-2/EN352-3

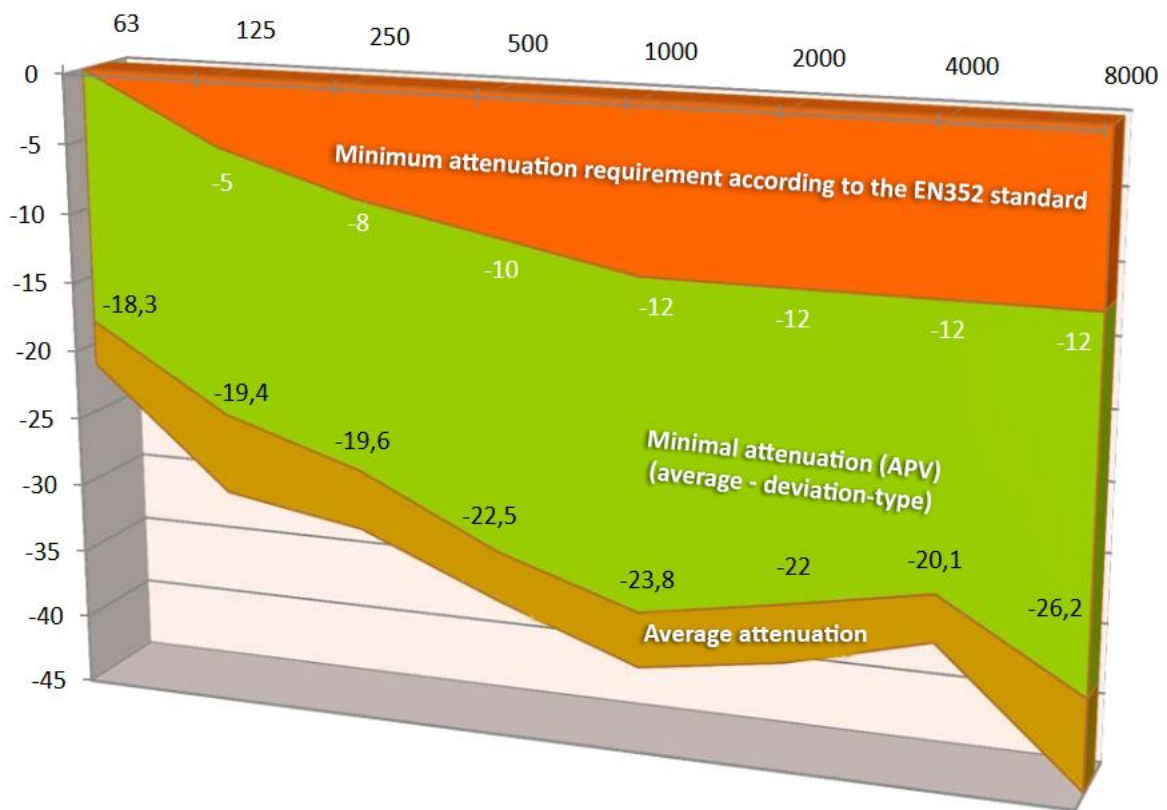


Figure 2: Graphical representation of attenuation values in dB of Table 3. For information, the minimum attenuations as per the EN352 standard were added (in white) as well as the APV corresponding to the mean value minus standard deviation (in black).

Frequencies in Hz	63	125	250	500	1000	2000	4000	8000
Minima	-	-5	23.9	26.1	27.8	26.2	23.5	32.8

Table 4: Minimum attenuation according to EN352

When acoustic tests are performed according to 13819-2, the attenuation of the hearing protectors (APV) should not be less than the minimum in Table 4.

5.1.1.1 Standard deviations

The standard deviations shown on the third line of Table 3 show the dispersion of attenuation values for all subjects during certification measures.

In theory, the weaker the standard deviations, the better repeatability/reliability the hearing protector exhibits during its implementation. The INRS (National Institute for Research and Safety) suggests to subtract not one, but two, standard deviations to approach closer to the attenuation of the hearing protector when worn.

Table 5 shows the average standard deviations by category of HPD. We see in this table that the differences between each type of HPD range from 3.44 for ear muffs and 5.53 for earplugs requiring molding.

<i>Categories of HPD</i>	<i>Average standard deviations Type by category</i>	<i>Number of HPDs analyzed</i>
Ear muffs	3.44	104
Customized earplugs	4.07	252
Canal caps	4.11	19
Preformed earplug	5.40	30
Earplug to be molded	5.53	43

Table 5: Average standard deviations by category of HPD.

5.1.1.2 Do all HPDs marketed have CE certification?

As discussed in the previous chapter, in order to be certified, a hearing protector will have to undergo a number of test measurements. These certifications to obtain the CE mark are binding and costly, since they must be fully funded by the manufacturer; some manufacturers ignore this step to market their products at a low price. The HPD database analyzed consisted of 460 HPDs, as follows:

- 288 models were identified as having the CE mark, which accounted for 63% of HPD
- 172 models, i.e. 37% of models sold, are not certified for the following reasons:

- 17 models have lower attenuation than the minimum set by EN352 - certain models sold by the same manufacturer are assigned a different name for marketing or economic reasons. It is therefore difficult to determine whether the characteristics of the HPD match those of the certified model.

- Some manufacturers use a certification issued in the name of another manufacturer, claiming that they use the same acoustic filters, while the protective casing, which constitutes the main element of attenuation and whose manufacturing quality differs widely from one manufacturer to another, is not at all taken into account in the practice, which is rather curious and objectionable. Although some controls are carried out by the DGCCRF (General Directorate for Competition Policy, Consumer Affairs and Fraud Control), everyone must be vigilant in verifying if the manufacturer or distributor has the "CE certification".

37% of models sold are not CE certified

bearing the model name and possibly the filter, but above all, the name of the manufacturer. The two products most concerned by these actions are the products using the filter "Jrenum" certified by the eponymous company in early 1990, whose certification is used by many manufacturers throughout Europe, and also the filter of the North American manufacturer Etymotic Research known as "ER" and certified in Europe by two manufacturers: Dutch Elacin and English ACS. The Elacin certification which resells this filter in Europe is then used by several manufacturers.

5.2 Range of attenuation

An attenuation range corresponds to the entire range of attenuation indices (SNR) available for a category of hearing protectors. The range extends, for example, from 19 to 35 dB for ear muffs, which means that the models in this category are available with attenuation from 19 dB. The ones with the most attenuation in this category have an SNR of 35 dB. We see in Figure 2 that the attenuations spread across all categories range from 10 dB (SNR) to 39 dB. There is, at the time of drafting this document, no certified hearing protector with an SNR less than 15 dB. Therefore, the models showing a SNR below this value have not been certified or failed during the certification. These may possibly be marketed as protectors for comfort, but never as personal protective equipment against noise (PPE).

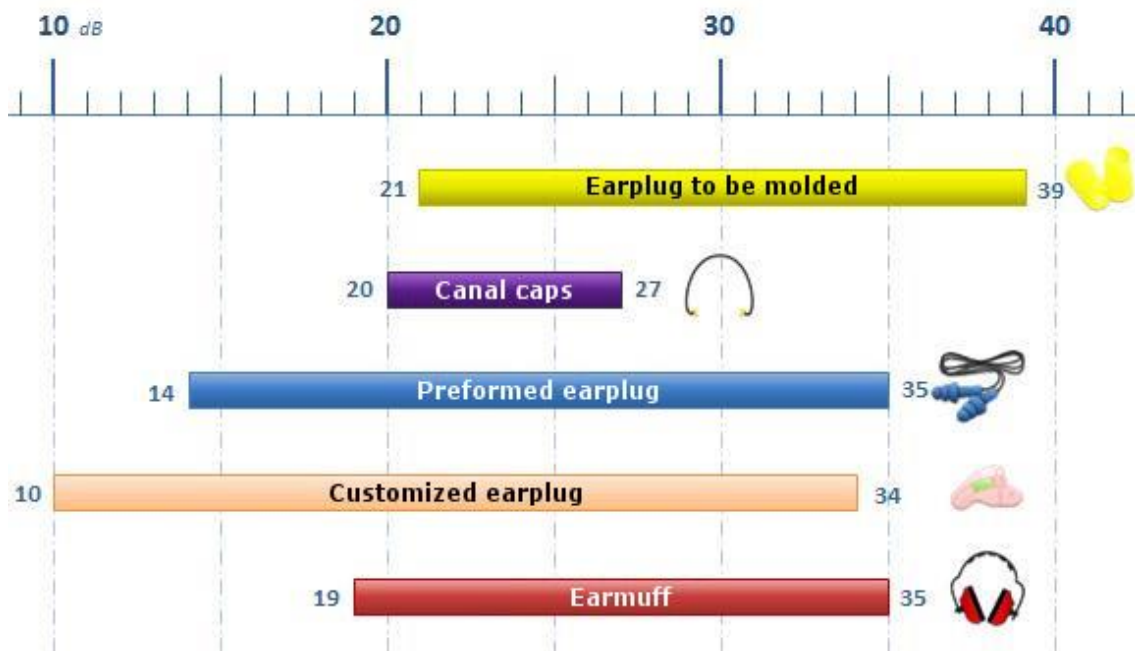


Figure 3: Attenuation range for each category of HPD; the attenuation value is in SNR.

5.3 Attenuation slope

Each protector belongs to a category (ear muff, earplugs requiring molding, etc.), with its attenuation index (SNR). We will now focus on its attenuation slope. This feature will help us select the hearing protector best suited to a given situation.

The need to communicate, the need to perceive one's environment without distortion, hearing loss, etc. requires relatively flat attenuation (NEXER, 2011) (EN 458, 2005). Some work activities or professions require a high attenuation at high frequencies, while others require low-frequencies.

We shall see how to determine the attenuation profile of a hearing protector.

Calculating the attenuation slope of a HPD is done using two of the three averages of attenuation provided by the manufacturers, the "HML" values. They provide information on the average attenuations at high (H), medium (M), and low (L) frequencies.

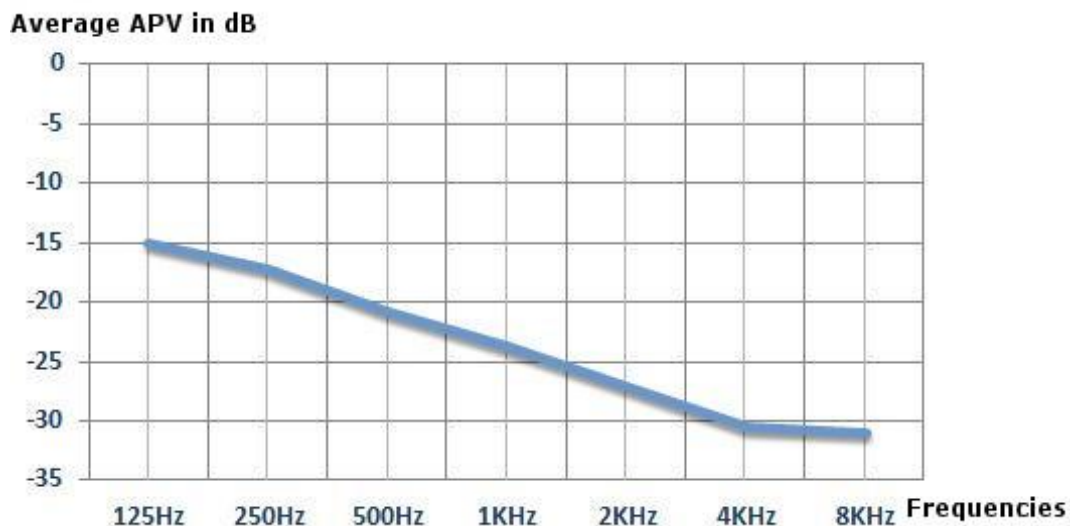


Figure 4: Average slope of all analyzed HPDs

Figure 4 corresponds to the average attenuation (APV) of our HPD database (excluding frequency 63 Hz), and shows that the attenuation slope of HPD generally descends from low frequency to high frequency.

Low frequencies are thus less attenuated than higher frequencies. The average of the "HML" values gives us 27/22/19.

The calculation as follows, "P" representing the value of the slope:

$$P = (H - L)$$

Example with the average values of our HPD database (H=27/M=22/L=19)

$$P = (27 - 19) = 8$$

The average slope of our HPD database is thus equal to "8".

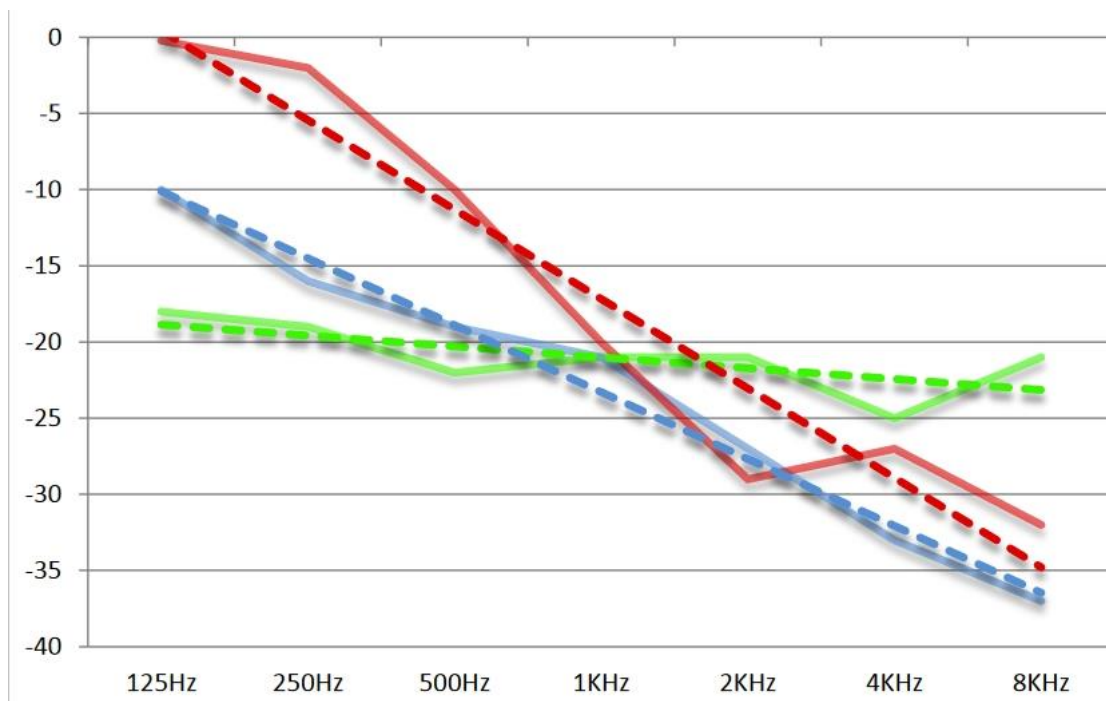


Figure 5: Three examples of slopes: an average slope of 10 in blue, significant slope of 20 in red, and given in green is the slope of an HPD with uniform response at all frequencies, whose slope = 0. Linear trend curves are shown in dotted lines.

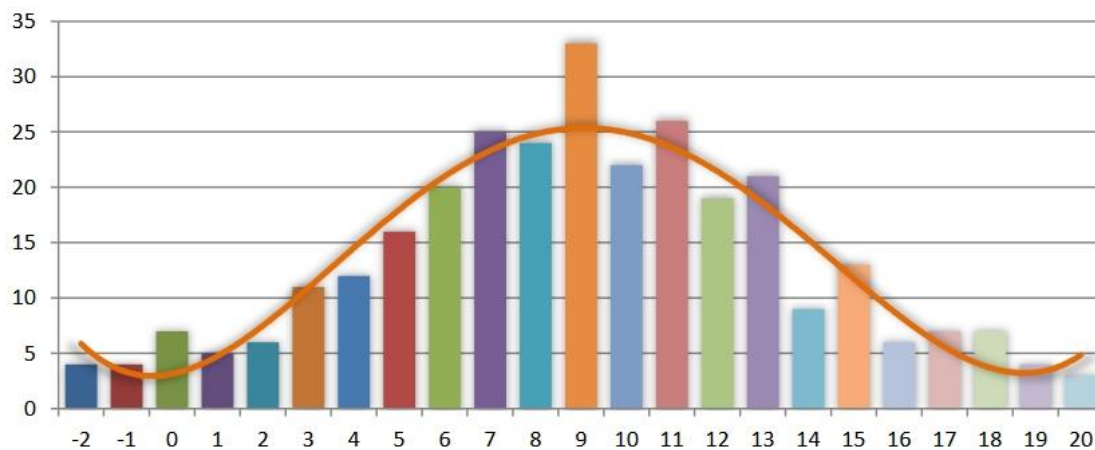


Figure 6: Distribution of slopes of the HPD database comprising 460 models. On the X-axis, the slopes (-2 to 20), on the Y-axis the number of HPD corresponding to this slope.

The closer the slope is to zero, the more the attenuation is said to be "uniform" across all frequencies; the closer it is to the value "20", the less the attenuation is uniform

and therefore the hearing protector distorts the sound to a greater degree by attenuation. Activities requiring noise protection without having excessive distortion (communication, perception of sound signals, music, etc.) must select protectors with the weakest slope.



Figure 7: Pictogram of identification of the attenuation

During a loud music concert, a hearing protector whose attenuation slope is equal to or less than +2 or -2 is highly recommended.

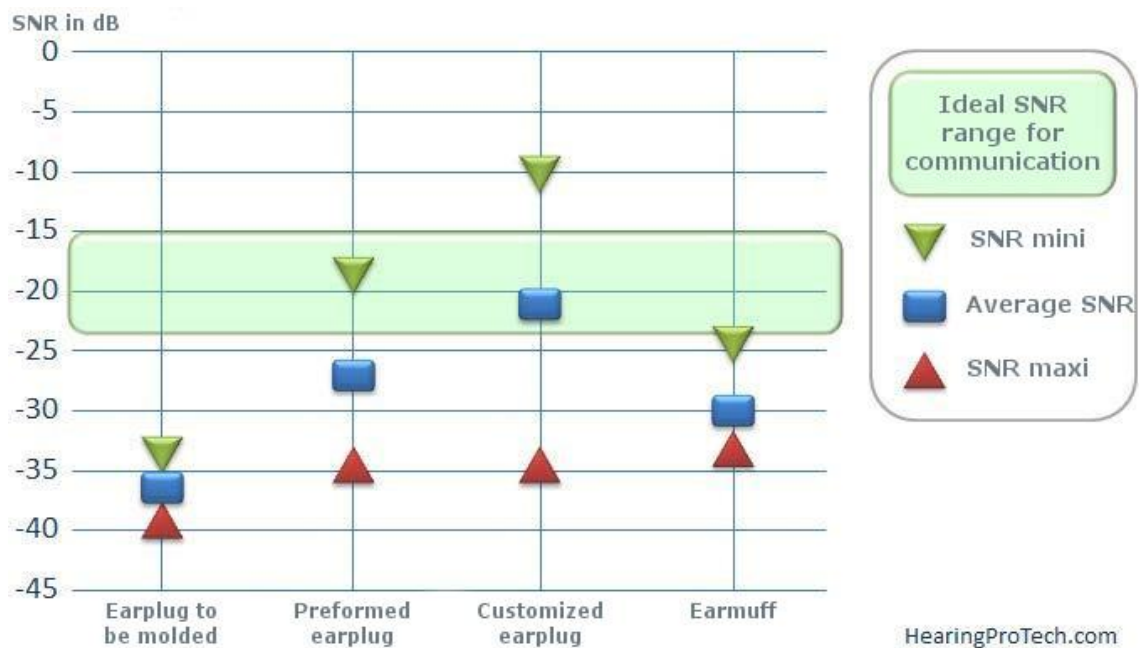


Figure 8: Distribution of min, max SNR and averages for the categories of HPD whose attenuation slope is less than or equal to 5.

Figure 8 shows the distribution of minimum, maximum, and average attenuations for categories of hearing protectors with relatively flat attenuation. (Slope ≤ 5). We note that a flat attenuation is not necessarily synonymous with good communication. A completely sealed HPD provides a relatively flat attenuation, but so does a very high SNR that is completely unsuitable for a minimum perception. The sound is not distorted but attenuated to such an extent that it is no longer audible. The ideal range to communicate with a hearing protector whose attenuation is flat, is between 15 and 23 dB of SNR when the user is exposed to noise levels greater than 85 dB (A).

Conclusion: Ideal attenuation for communication must be:

- 1 - uniform across all frequencies
- 2 - less than 24dB of SNR to permit hearing
- 3 - able to provide sufficient attenuation (see the minimum as per EN352) for CE certification.

5.4 What is the efficiency of attenuation?

A literature study by INRS (Kusy, 2008) demonstrates the significant differences between the values displayed by the HPD manufacturers (measured at CE certifications) and the actual values (*in situ*).

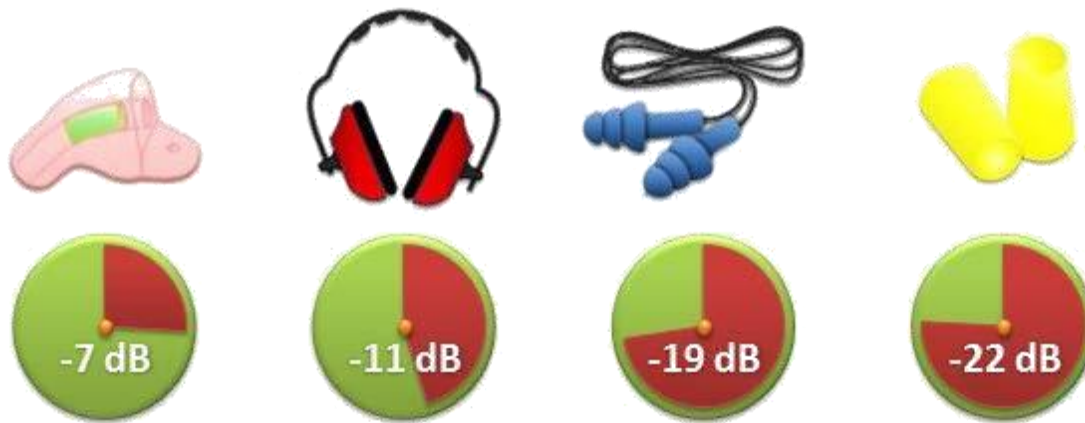


Figure 9: Average differences between attenuation values displayed by manufacturers and the attenuation values measured in situ by category of HPD (Kusy, 2008).

We see the importance of differences, especially in the "earplug" and "requiring molding" categories, for which a difference of 20 dB SNR exists between the SNR claimed by the manufacturer and the attenuation that actually protects the user on the job. These significant differences on the standard earplugs are essentially the result of a lack of training in their implementation.

Given these deviations, what is the actual effectiveness of hearing protectors?

	earplugs requiring molding (43)	preformed earplugs (31)	customized earplugs (263)	ear muffs (104)
A - Average theoretical SNR	32	25	23	29
B - Difference observed	22	19	7	11
C - Average SNR observed	10	6	16	18
D - Theoretical weighting	31%	24%	70%	62%

Table 6: The estimate of efficiency of categories of HPD, and the number of HPD for each category is indicated in parenthesis.

Line A - "Average theoretical SNR": we calculate the average of all SNR values for a category of HPD

Line B - "Difference observed" see Figure 9

Line C - "Average SNR observed": the average of line A from which is subtracted the average deviation of line B

Line D - "Theoretical weighting" Efficiency percentage for each category of HPD, calculated by comparing $(C/A = D)$ the difference between the theoretical mean (A) displayed by manufacturers and the average mean recorded in situ (Line C) highlighted in the bibliographical study of the INRS (Kusy, 2008). This weighting could be applied to the theoretical attenuation value of an HPD to determine the actual attenuation.

6 Bibliography

EN 458. (2005). *EN 458 - Personal Hearing Protection - Recommendations for selection, use, care and maintenance.*

Kusy, A. (2008). In situ sound attenuation of personal hearing protectors. *ND 2295*. INRS.

NEXER, G. (2011). *Select a personal hearing protection device with uniform response attenuation*
HearingProTech.

7 Appendix 1:

List of manufacturers / distributors of the products constituting the HPD database.

Types of hearing protectors	Manufacturers, distributors
Earplugs to be molded	3M, Blox, Howard Leight, Moldex, Quies, Uvex
Canal caps	3M, Howard Leight, Moldex, Uvex
Preformed earplugs	3M, ACS, Alvis Audio, Blox, Earsonic, Etymotic Research, Howard Leight, Moldex, Uvex
Customized earplugs	3M, Acs, Alpine, Alvis Audio, Api Pro Santé, AudioLab Swiss, Audio Protect, Auditech, Cotral Laboratory, Dreve, Erafoon, Earsonic, Egger, Elacin, Elstar, Epi 3d, In Ear, Infield, Intersafe Elcea, Interson Protac, Jrenum, Neuroth, Phonak Protecsys, Sonomax Surdifuse, Uvex, Variphone
Ear muffs	3M, Howard Leight, Moldex, Silenta, Uvex

Manufacturers	No. of HPD analyzed	CE ¹	100% CE manuf. ²
3M	67	82%	Yes
Acs	9	89%	Yes
Alpine	4	75%	Yes
Alvis Audio	2	100%	Yes
Api Pro Santé	11	100%	Yes
Audio Lab Swiss AG	3	67%	No
Audio Protect AG		79%	No
Auditech Innovations	10	100%	Yes
Blox	5	80%	No
Cotral Laboratory	17	100%	Yes
Dreve Otoplastik	6	100%	Yes
Earfoon DE GMBH	25	72%	Yes
Earsonic	3	100%	Yes
Egger Otoplastik	4	100%	No
Elacin	22	86%	Yes
Elstar Prevention	6	83%	No
Epi 3D	8	100%	No
Etymotic Research	1	100%	Yes
Howard Leight - Sperian	57	100%	Yes
in Ear	8	100%	No
Infield Safety	18	89%	No
Intersafe Elcea France	22	91%	No
Interson Protac	14	93%	No
Jrenum	8	100%	Yes
Moldex	16	100%	Yes
Neuroth AG	3	100%	No
Phonak	3	100%	Yes
Protecsys	8	100%	No
Quies	2	100%	Yes
Silenta	28	100%	Yes
Sonomax	2	0%	Yes
Surdifuse	9	78%	No
Uvex Arbeitsschutz gmbh	38	100%	No
Variphone	6	100%	Yes

Table 7: List of manufacturers/distributors in alphabetical order, with the number of products analyzed.

¹ The CE column shows the proportion of models that meet the CE certification in terms of minimum attenuation; a manufacturer whose percentage is less than 100% thus markets products that do not have the CE mark. Such marketing is not prohibited from individual customers, but employees are not permitted to use such products, since in this case, the protector is not recognized as PPE (Personal Protective Equipment).

² The column 100% Manuf. EC indicates whether the manufacturer has obtained certification for the products he manufactures and sells. Otherwise it can be understood that the products are manufactured and marketed using the certification of another manufacturer whose manufacturing methods could be different.