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The influence of frequency component content on the selection result of hearing protectors

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Hearing protectors are selected for workstation noise using the octave band (OB), HML and SNR methods. The purpose of this study was to determine how the frequency components of the noise can affect the selection of hearing protectors. In total, 55 hearing protectors were selected for four types of real occurring noise, high-frequency noise, low-frequency noise and eight simulated noises. Analysis showed that the noise type affects the accuracy of selection carried out using the HML and SNR methods. For a noise with dominant frequency components, the result for selection carried out using the HML method deviates from the result using the OB method by 7 and 9 dB for earmuffs and earplugs, respectively. The study shows that use of the HML and SNR methods may lead to wrong assessment of the effectiveness of hearing protection with the selected hearing protectors.

Keywords: selection of hearing protectors; earmuffs; earplugs; sound attenuation; noise

1. Introduction

Exposure of workers to noise in industrial settings is a common phenomenon. For example, in Poland in 2019 this concerned 186,400 people [1]. For a significant number of these workers, the only possible way to reduce exposure to noise was to use hearing protectors. However, only correctly used and selected hearing protectors can fully protect the hearing of their users. Unfortunately, previous studies indicate that there are differences between the assumed effectiveness of hearing protection resulting from the use of hearing protectors based on the sound attenuation values presented by manufacturers in user manuals and the effectiveness of protection under real conditions [1–5].

There are several reasons why these differences occur. The reason for these differences lies, e.g., in the fact that, in accordance with Standard No. ISO 4869-1:2018 [6], studies conducted to determine the sound attenuation of hearing protectors are performed under laboratory conditions by a group of trained subjects on brand-new samples of hearing protectors, whereas in real conditions the use of hearing protectors often differs from laboratory conditions. For example, workers often use worn-out hearing protectors with limited effectiveness. Studies indicate that the attenuation of hearing protectors which were exposed to typical weather conditions may decrease by as much as 10 dB in comparison to new ones [7,8]. Another factor affecting the attenuation properties of used hearing protectors was the presence of damage [9]. Moreover, in a working environment, it is quite common for employees to use hearing protectors and other personal protective equipment (PPE) at the same time, resulting in leakages and reduced attenuation efficiency [10,11]. For example, the use of safety glasses simultaneously with earmuffs may reduce the attenuation of earmuffs by 14 dB in the lower frequency range [12]. An even higher reduction of earmuff attenuation of up to 40 dB was observed when full masks were used [13,14].

Another reason for the failure of hearing protectors to provide adequate protection is that workers do not pay due attention to wearing or do not know how to wear hearing protectors correctly [15], or do not have the appropriate knowledge in this regard, i.e., no training in wearing hearing protectors [16–18].

Another problem that may affect the reduced overall effectiveness of hearing protectors is how they are selected. Hearing protectors are selected in accordance with the requirements of Standard No. EN 458:2016 [19], which describes the methods of selection of hearing protectors: the octave band (OB), HML and SNR methods. The OB method is considered the most accurate and therefore the reference method for the selection of hearing protectors (Standard No. EN 458:2016 [19]). In contrast, the SNR method is considered the least accurate. There are few studies comparing the selection result obtained using different methods. One of the studies related to this issue was the research on the selection of level-dependent hearing protectors [20]. This research has shown that the calculated *A*-weighted sound pressure level under hearing protectors

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for impulse noise could vary by 4 dB depending on the selection method chosen. However, there are no studies comparing the results of selection performed using different methods for continuous noise. The purpose of this study was to determine how the distribution of frequency components in the continuous noise spectrum may affect the result of the selection of hearing protectors. To determine this, the selected hearing protectors were assigned to four types of noise, which occurred under real conditions, two types of noise described in Standard No. ISO 4869-2:2018 [21] and eight simulated noises.

2. Materials and methods

2.1. *Methods for the selection of hearing protectors*

The selection of hearing protectors involves determining the *A*-weighted sound pressure level under hearing protectors (L'_A).

When selecting hearing protectors according to the OB method, the L'_A value is determined according to Equation (1):

$$L'_A = 10\text{Log} \sum_{f=125}^{8000} 10^{0,1(L_f + K_{Af} - (m_f - s_f))}, \qquad (1)$$

where L'_A = *A*-weighted sound pressure level under hearing protectors; L_f = octave band sound pressure level of noise in octave band f; K_{Af} = frequency weighting *A* for octave band f; m_f = mean sound attenuation of the hearing protectors; s_f = standard deviation; f = octave band centre frequency in the range of 125–8000 Hz.

When the HML method is used for the selection of the hearing protectors, the L'_A value is determined according to Equation (2):

$$L'_A = L_A - PNR, \qquad (2)$$

where L'_A = *A*-weighted sound pressure level under hearing protectors; L_A = *A*-weighted sound pressure level of noise; *PNR* = predicted noise level reduction. The *PNR* value is determined according to Equation (3) or (4):

$$PNR = M - \frac{H - M}{4} \cdot (L_C - L_A - 2\text{ dB}) \quad \text{for } L_C - L_A \leq 2\text{ dB}, \qquad (3)$$

$$PNR = M - \frac{M - L}{8} \cdot (L_C - L_A - 2\text{ dB}) \quad \text{for } L_C - L_A > 2\text{dB}, \qquad (4)$$

where *PNR* = predicted noise level reduction; *M* = medium-frequency attenuation value; *H* = high-frequency attenuation value; L_C = *C*-weighted sound pressure level of noise; L_A = *A*-weighted sound pressure level of noise; *L* = low-frequency attenuation value. The *H*, *M* and *L* parameters are described in Standard No. ISO 4869-2:2018 [21].

When the SNR method is used for the selection of the protectors, the L'_A value is determined according to Equation (5):

$$L'_A = L_C - SNR, \qquad (5)$$

where L'_A = *A*-weighted sound pressure level under hearing protectors; L_C = *C*-weighted sound pressure level of noise; *SNR* = single number rating (attenuation parameter of hearing protectors described in Standard No. ISO 4869-2:2018 [21]).

2.2. *Type of noise*

The selection of hearing protectors was carried out for four types of noise occurring in real workstations. Type 1 was low-frequency noise with a constant decrease in the sound pressure level as a function of frequency. This noise was observed at workstations in steelworks and was characterized by an *A*-weighted equivalent sound pressure level ($L_{A\text{eq}}$) and *C*-weighted equivalent sound pressure level ($L_{C\text{eq}}$) of 105.0 and 109.5 dB, respectively. The spectrum of the second selected noise (type 2) contains clearly dominant components in the frequency bands of 125 and 4000 Hz. Measurement of the parameters of this noise was carried out at workstations in a plant producing aluminium packaging and resulted in an $L_{A\text{eq}}$ and $L_{C\text{eq}}$ value of 107.9 and 109.3 dB, respectively. Type 3 noise was characterized by dominant components in the frequency bands of 2000 Hz. This noise comes from running aircraft engines when these engines were tested. The $L_{A\text{eq}}$ and $L_{C\text{eq}}$ value of this noise was 114.3 and 112.8 dB, respectively. The spectrum of type 4 noise contains dominant components in the frequency bands of 1000 Hz. This type of noise was observed in a paper pulp factory. The $L_{A\text{eq}}$ and $\text{L}_{C\text{eq}}$ value of this noise was 106.7 and 107.5 dB, respectively. The octave bands sound pressure level of noise types 1, 2, 3 and 4 is shown in Figure 1. In addition, the selection of hearing protectors was also carried out for two types of noise described in Standard No. ISO 4869-2:2018 [21]. The first is typically high-frequency noise ($L_{A\text{eq}}$ = 100 dB and $L_{C\text{eq}}$ = 98.8 dB). The second is low-frequency noise ($L_{A\text{eq}}$ = 100 dB and $L_{C\text{eq}}$ = 108.4 dB). The octave bands sound pressure level of these types of noise is shown in Figure 2.

Besides the four types of noise that occurred at the real workstations and the two types of noise described in Standard No. ISO 4869-2:2018 [21], in order to carry out a detailed analysis of the impact of the content of frequency components on the result of the selection of hearing protectors, eight simulated noises were used during the selection process. First, the hearing protectors were selected for noise with a uniform sound pressure level of 95 dB throughout the entire frequency range. Next, the hearing protectors were selected for seven noises contained a dominant component of 110 dB in one of the frequency bands 125, 250, 500, 1000, 2000, 4000 and 8000 Hz. For

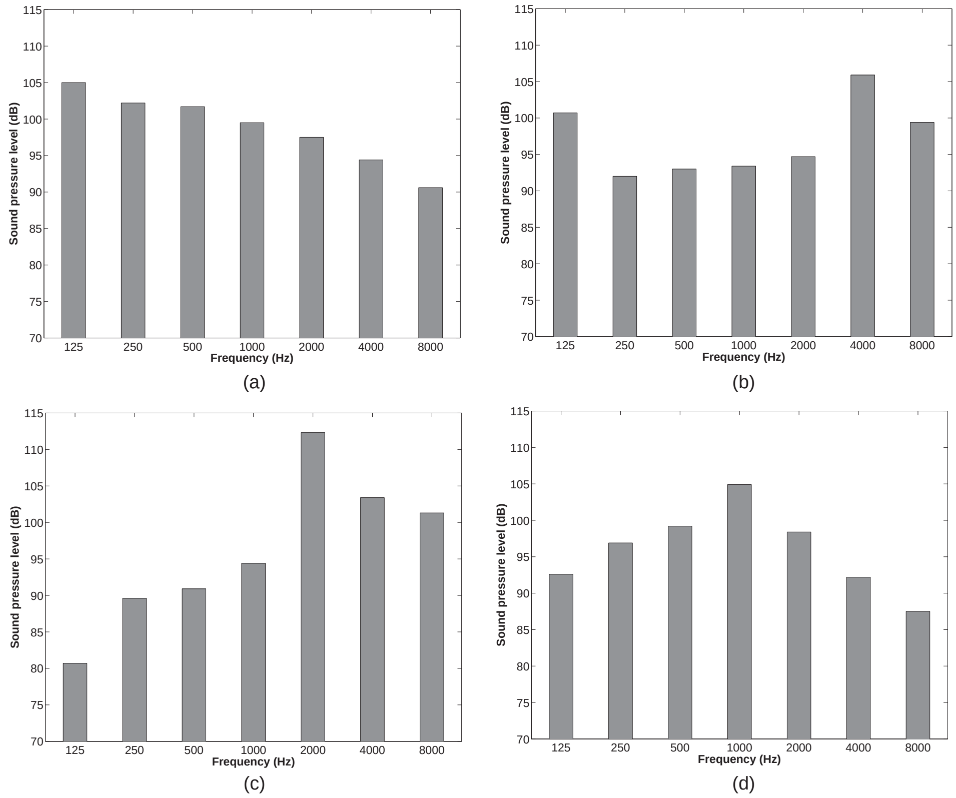

Figure 1. Octave band sound pressure level of noises occurring at real workstations: (a) type 1; (b) type 2; (c) type 3; (d) type 4.

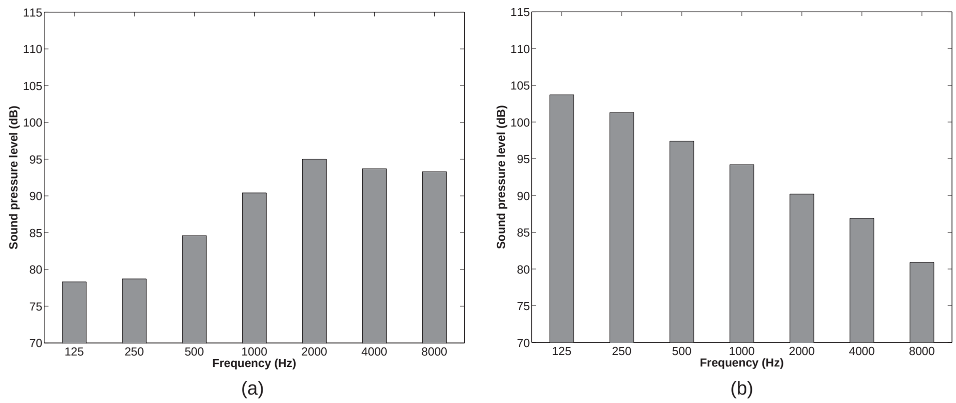

Figure 2. Octave band sound pressure level of noises described in Standard No. EN ISO 4869-2:2018 [21]: (a) high-frequency noise; (b) low-frequency noise.

the remaining bands, i.e., except for the one in which the dominant component was present, the sound pressure level was 95 dB. In order to determine the impact of the frequency components on the selection result of hearing protectors, the selection result obtained in the first situation (an uniform sound pressure level) was compared to the selection result when the sound pressure level of noise contained a dominant component. The octave bands sound pressure level of simulated noises is shown in Figure 3. Values of *A*-weighted and C-weighted sound pressure of simulated noises are presented in Table 1.

2.3. *Hearing protectors*

The selection was carried out for 55 models of hearing protectors commonly used in industry, including 26 models of earmuffs and 29 models of earplugs by different manufacturers. The earmuffs were characterized by an *SNR* parameter value of 21–37 dB, whereas the earplugs were characterized by an *SNR* parameter value of 14–39 dB. The detailed values of the *SNR* and *H*, *M* and *L* parameters for the individual earmuffs and earplugs are presented in Tables 2 and 3, respectively.

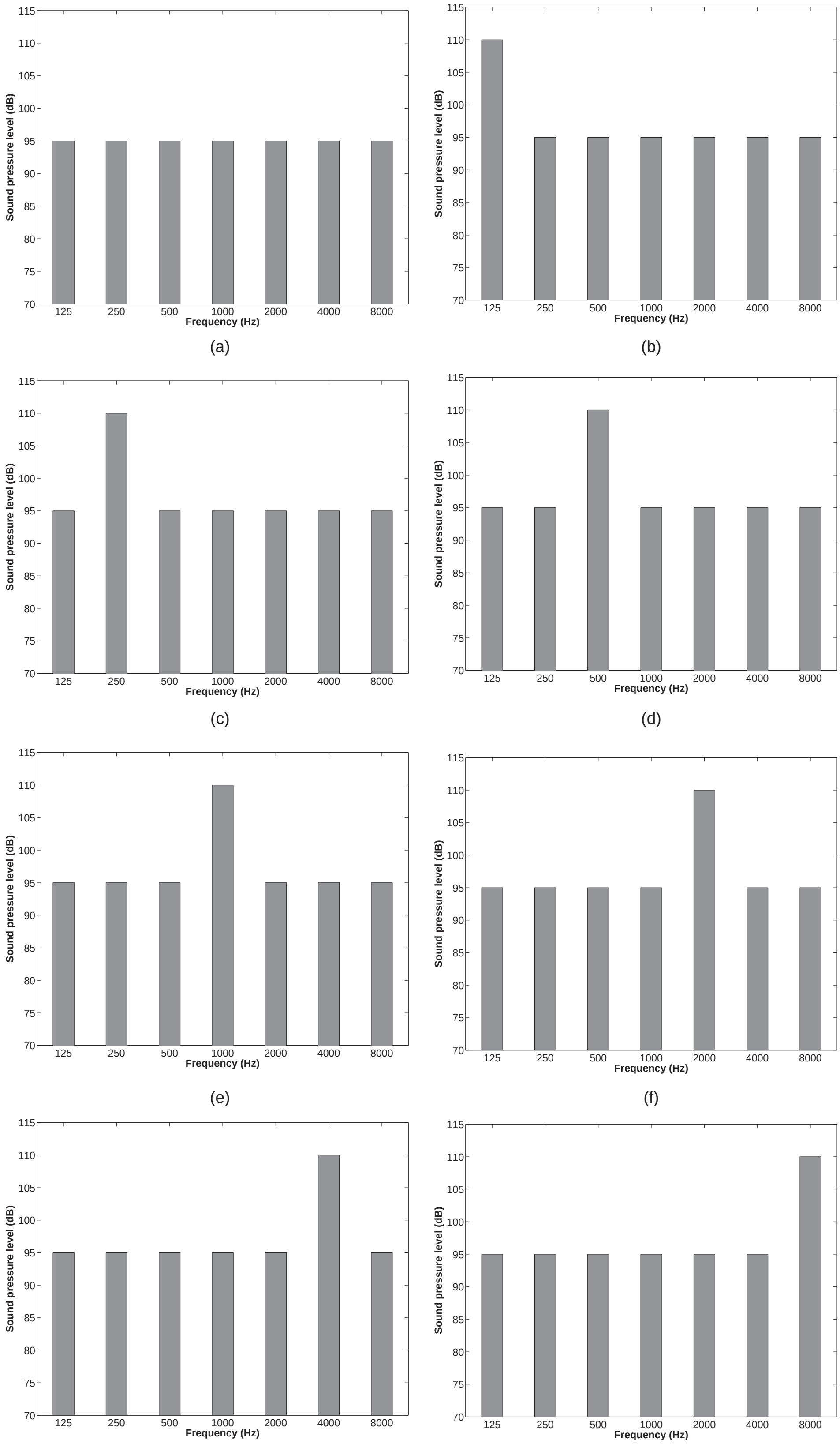

Figure 3. Octave band sound pressure level of simulated noises: (a) uniform sound pressure level; (b) dominant component of frequency band 125 Hz; (c) dominant component of frequency band 250 Hz; (d) dominant component of frequency band 500 Hz; (e) dominant component of frequency band 1000 Hz; (f) dominant component of frequency band 2000 Hz; (g) dominant component of frequency band 4000 Hz; (h) dominant component of frequency band 8000 Hz.

Table 1. Values of *A*-weighted and C-weighted sound pressure of simulated noises.

Dominant component of frequency bands	*A*-weighted sound pressure (dB)	C-weighted sound pressure (dB)
Uniform	102.0	103.0
125 Hz	102.6	110.5
250 Hz	105.0	110.7
500 Hz	107.7	110.7
1000 Hz	110.5	110.7
2000 Hz	111.6	110.5
4000 Hz	111.4	110.0
8000 Hz	109.7	108.3

Table 2. Values of attenuation parameters for earmuffs.

Earmuff number	*SNR* (dB)	*H* (dB)	*M* (dB)	*L* (dB)
1	27	32	25	15
2	31	34	29	20
3	35	40	32	23
4	27	32	24	16
5	31	34	29	20
6	33	35	30	25
7	33	36	30	22
8	37	37	35	27
9	30	34	28	19
10	30	31	28	23
11	31	31	29	23
12	34	33	32	27
13	30	32	28	21
14	32	33	30	24
15	36	37	34	26
16	28	31	25	19
17	25	27	22	15
18	27	31	24	16
19	32	32	29	23
20	26	30	23	15
21	30	35	28	18
22	33	34	31	22
23	29	31	27	19
24	27	35	24	15
25	21	26	18	11
26	24	28	21	13

Note: *SNR*, *H*, *M* and *L* parameters are described in Standard No. ISO 4869-2:2018 [21]. *H* = high-frequency attenuation value; *L* = low-frequency attenuation value; *M* = medium-frequency attenuation value; *SNR* = single number rating (attenuation parameter of hearing protector).

2.4. *Statistical analysis*

A statistical analysis of the data obtained was carried out in order to assess whether there were significant differences in the results of selection of hearing protectors for different types of noise. Data were analysed using MATLAB version R2010b. The analysis used the Student's *t* test and Wilcoxon test.

Table 3. Values of attenuation parameters for earplugs.

Earplug number	*SNR* (dB)	*H* (dB)	*M* (dB)	*L* (dB)
1	35	34	32	31
2	29	31	25	22
3	37	37	34	31
4	34	32	32	31
5	37	36	35	34
6	37	36	34	34
7	33	33	30	29
8	24	26	20	18
9	30	29	27	25
10	23	24	20	17
11	30	32	27	23
12	20	21	18	14
13	28	29	25	24
14	23	26	18	17
15	24	27	20	18
16	23	25	19	17
17	36	34	34	31
18	25	27	22	20
19	26	30	22	19
20	34	37	31	27
21	37	37	34	31
22	28	30	24	22
23	21	25	17	14
24	14	22	10	5
25	32	33	28	25
26	20	25	17	10
27	39	39	36	34
28	33	32	29	29
29	24	25	20	19

Note: *SNR*, *H*, *M* and *L* parameters are described in Standard No. ISO 4869-2:2018 [21]. *H* = high-frequency attenuation value; *L* = low-frequency attenuation value; *M* = medium-frequency attenuation value; *SNR* = single number rating (attenuation parameter of hearing protector).

3. Results and discussion

The results of the selection of hearing protectors for the noise occurring at the workstations (noise types 1, 2, 3 and 4) are presented in Figures 4–11. The results of the selection of hearing protectors for the noises described in Standard No. ISO 4869-2:2018 [21] are presented in Figures 12–15.

When analysing the results of the selection of hearing protectors presented in Figures 4 and 5, it can be concluded that in the case of noise type 1 (low-frequency noise) there are no significant differences between the *A*-weighted sound pressure level obtained by different methods of selection. When comparing the selection of earmuffs, it can be observed that in the case of the OB and HML methods, the result of the selection coincides in most earmuffs (19 out of 26). For six earmuffs, the *A*-weighted sound pressure level calculated using the HML method is lower by 1 dB, and in one case it is higher by 1 dB. Slightly less consistency between the results of the selection is observed by comparing the OB and SNR methods. In this case, the

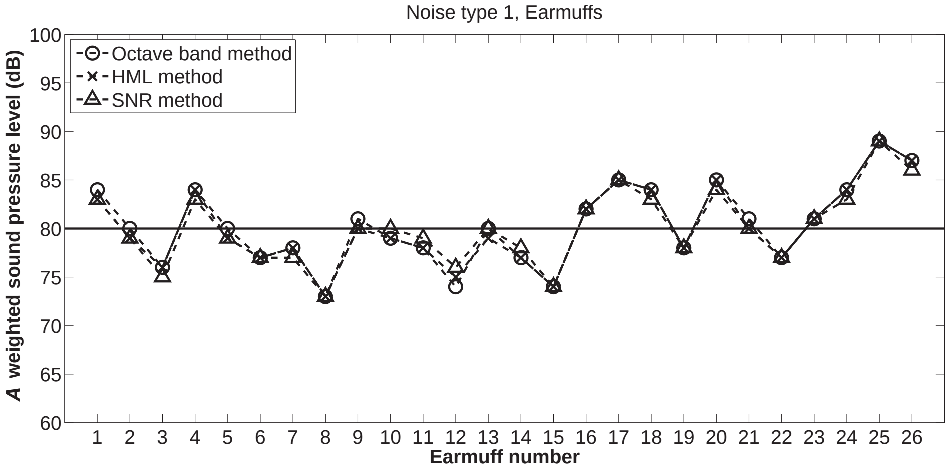

Figure 4. *A*-weighted sound pressure level under earmuffs selected for noise type 1.

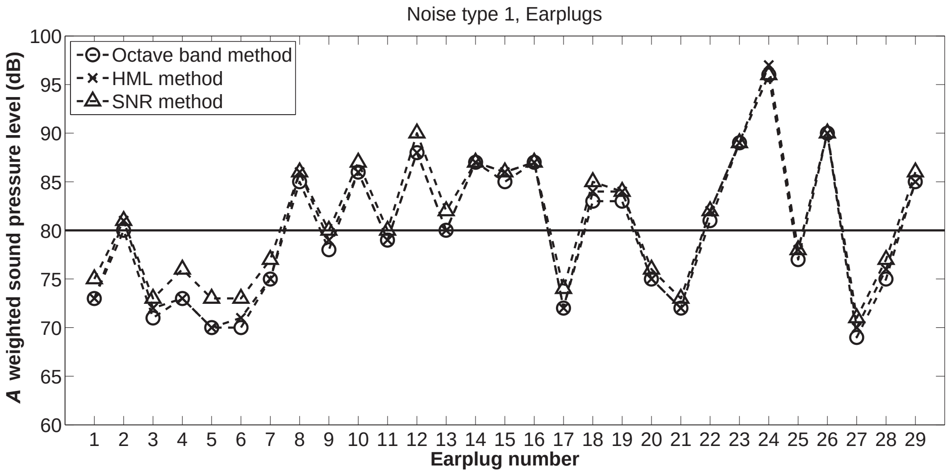

Figure 5. *A*-weighted sound pressure level under earplugs selected for noise type 1.

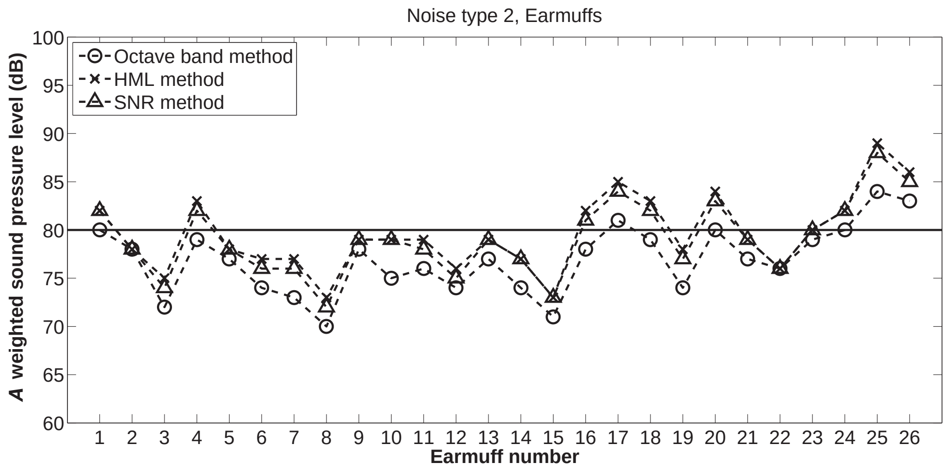

Figure 6. *A*-weighted sound pressure level under earmuffs selected for noise type 2.

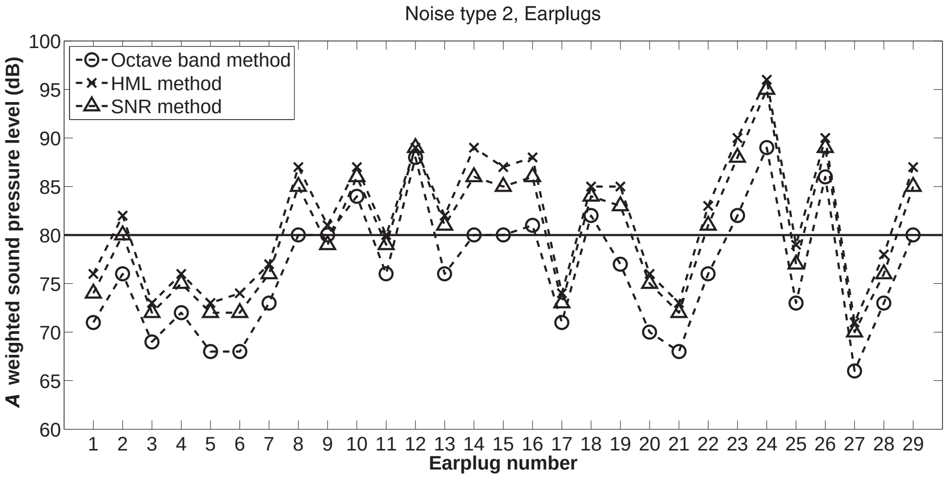

Figure 7. *A*-weighted sound pressure level under earplugs selected for noise type 2.

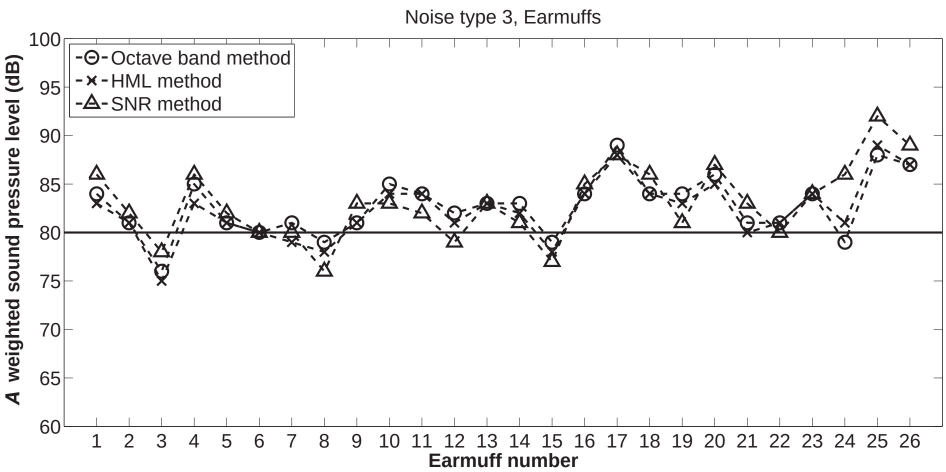

Figure 8. *A*-weighted sound pressure level under earmuffs selected for noise type 3.

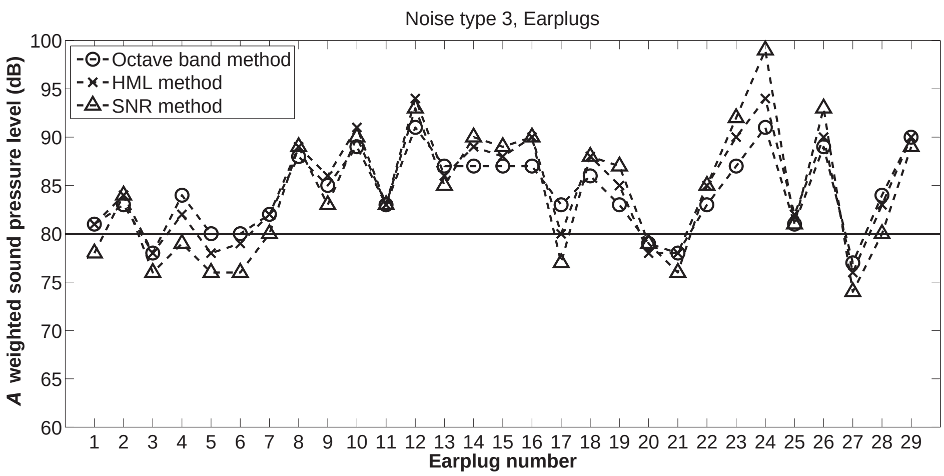

Figure 9. *A*-weighted sound pressure level under earplugs selected for noise type 3.

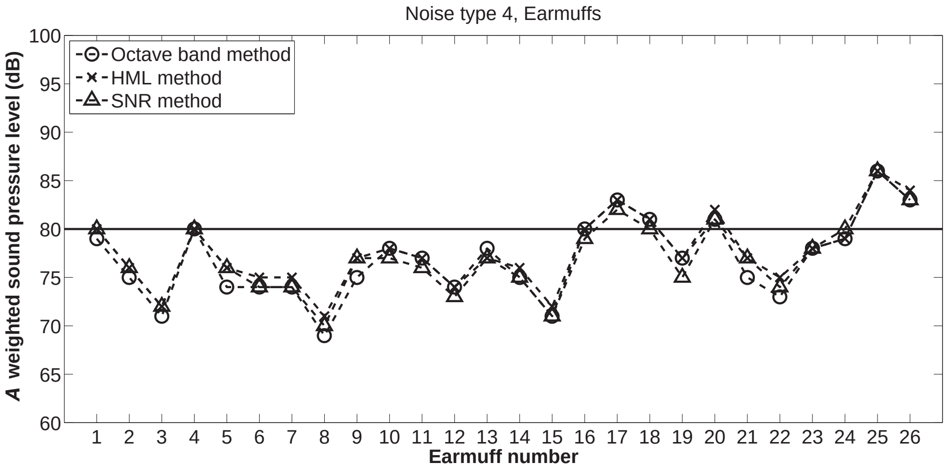

Figure 10. *A*-weighted sound pressure level under earmuffs selected for noise type 4.

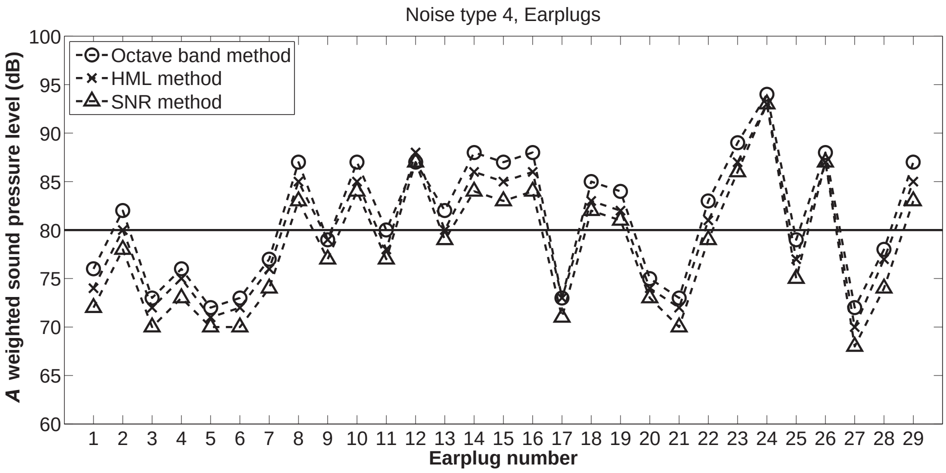

Figure 11. *A*-weighted sound pressure level under earplugs selected for noise type 4.

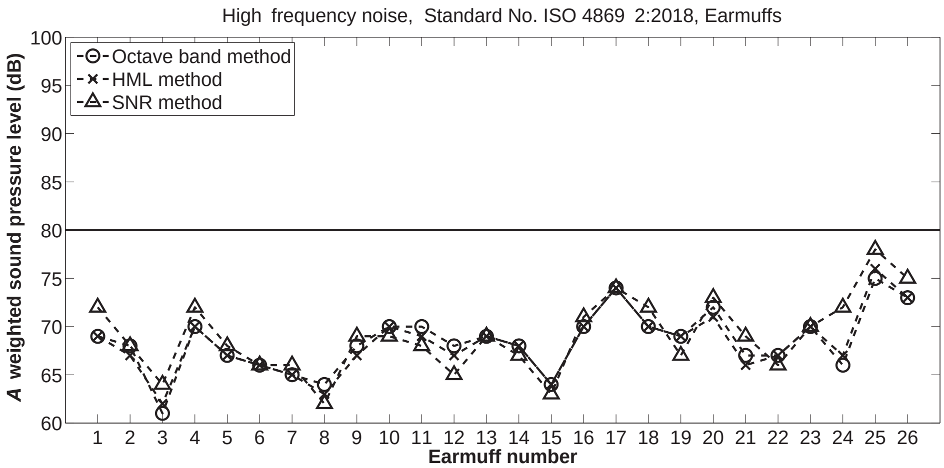

Figure 12. *A*-weighted sound pressure level under earmuffs selected for high-frequency noise described in Standard No. EN ISO 4869-2:2018 [21].

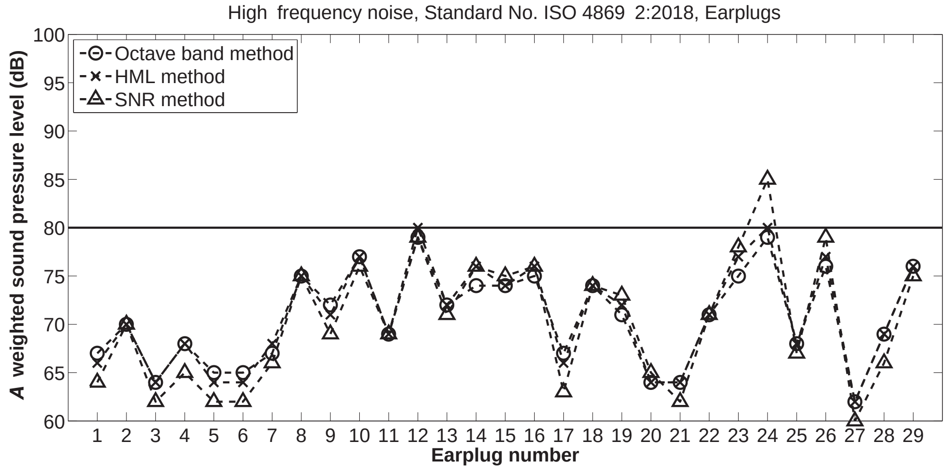

Figure 13. *A*-weighted sound pressure level under earplugs selected for high-frequency noise described in Standard No. EN ISO 4869-2:2018 [21].

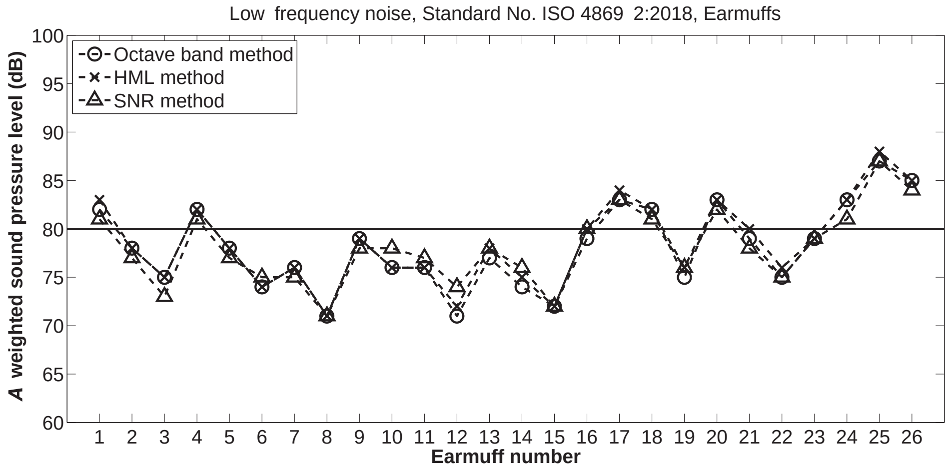

Figure 14. *A*-weighted sound pressure level under earmuffs selected for low-frequency noise described in Standard No. EN ISO 4869-2:2018 [21].

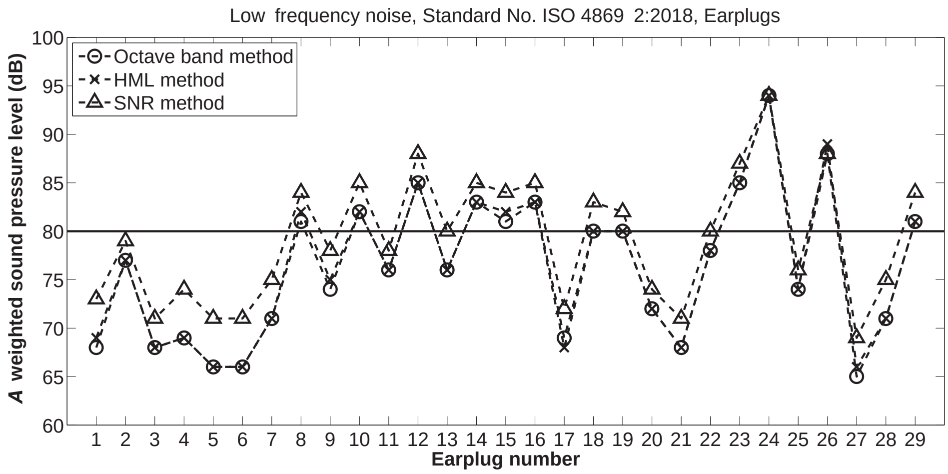

Figure 15. *A*-weighted sound pressure level under earplugs selected for low-frequency noise described in Standard No. EN ISO 4869-2:2018 [21].

result of the selection coincides in 10 earmuffs. For 12 earmuffs, the result of the selection using the SNR method is underestimated by 1 dB, and overestimated by 1 dB for three earmuffs and by 2 dB for one earmuff. There are also differences of 1 dB as a result of the selection carried out using the HML and SNR methods. However, in most cases (14 earmuffs), the selection using these methods results in compliance. In the case of the earplugs selected for noise type 1, there is a high correlation between the selection results obtained by the OB and HML methods. No difference is observed for 16 earplugs and only one difference of 1 dB occurs for 13 earplugs. Greater differences occur when the OB and SNR methods are compared. Full compliance between the selection methods occurs only in five earplugs. For the other earplugs, the SNR method underestimates the level of protection, i.e., it indicates higher *A*-weighted sound pressure level values than the reference OB method. The maximum difference in the selection result is 3 dB and refers to three earplugs characterized by high sound attenuation.

Significantly larger differences in the results of the selection of hearing protectors presented in Figures 6 and 7 were observed for noise type 2. Only in the case of two earmuffs was there a contradiction between the results of the selection obtained using the OB and HML or the OB and SNR methods. For the other earmuffs, the *A*-weighted sound pressure level under the earmuffs for the HML as well as the SNR method is 5 dB higher than that for selection using the OB method. A similar situation exists with earplugs. Selection using the HML or SNR methods indicates higher values of *A*-weighted sound pressure level under all earplugs than for the OB method. It should be noted that, in this case, larger differences in the result for selection of up to 9 dB occur when comparing the OB method with the HML method than when the OB method is compared with the potentially least accurate SNR method (maximum difference of 6 dB). The results of the selection of hearing protectors presented for noise type 2 indicate a potentially large dispersion of these results obtained by different methods.

When analysing the values of the *A*-weighted sound pressure level under hearing protectors in relation to 80 dB, which means that exceeding this value may result in a lack of adequate hearing protection, it can be concluded that in many hearing protectors the use of the HML or SNR methods provides a different assessment as to the effectiveness of hearing protection than the reference OB method. When applying the HML method, in as many as nine cases of earmuffs, it was concluded that these earmuffs provide insufficient hearing protection (sound attenuation is too low), while the selection result of the reference OB method indicates proper hearing protection in six out of those nine cases. The same is true for seven earmuffs and use of the SNR and OB methods. However, it should be noted that for the OB method the selection shows that lower values of *A*-weighted sound pressure level occur under hearing protectors than for the HML and SNR methods. This is all the more important as, despite the large differences from the OB reference method, this does not result in a situation in which hearing protectors that do not adequately protect the worker's hearing for noise type 2 are selected.

Also, large differences in the results of the selection of hearing protectors presented in Figures 8 and 9 were observed for noise type 3. Only in the case of three earmuffs and three earplugs was there a correlation between the selection results obtained by the OB and SNR methods. The maximum differences in the selection results obtained by these methods are up to 7 and 8 dB for earmuffs and earplugs, respectively.

Small differences in the results of the selection of earmuffs by different methods reaching a maximum 2 dB occur for noise type 4 (Figure 10). However, in the case of earplugs, a constant tendency is observed that the results of SNR selection in almost all cases are lower than is the case for the other two selection methods (Figure 11).

For both noise types 3 and 4, there is a situation where the *A*-weighted sound pressure level under some earplugs obtained with the SNR method is below 80 dB, which indicates a safe level of protection, while for the HML and SNR methods the level is above 80 dB, which indicates insufficient hearing protection.

After analysing the selection results of hearing protectors for the spectra described in Standard No. ISO 4869-2:2018 [21], it can be concluded that for both low-frequency noise and high-frequency noise the selection results for the earmuffs overlap or differ slightly (Figures 12 and 14). This is different for the earplugs, for which the result of selection with the OB and SNR methods in the case of high-frequency noise varied in the extreme case even by 6 dB (Figure 13).

Statistical analysis of the results of selection taking into account all earmuffs and all earplugs independently showed that only in the case of noise type 2 should the selection results obtained by different methods be treated as statistically significant. In the case of noise types 3 and 4, despite the occurrence of discrepancies between the selection results, the statistical analysis did not show that the discrepancies are statistically significant for the whole population of earmuffs and earplugs. The same is true for the noises described in Standard No. ISO 4869-2:2018 [21]. The p values for comparisons of the hearing protectors' selection results obtained by different methods are presented in Table 4.

In addition to the selection for noise occurring at workstations, an analysis of the impact of the frequency component content on the selection result was also carried out using eight simulated noises. The results of the analysis of this impact are shown in Figures 16 and 17. These figures present the number of hearing protectors for which there is a difference between the *A*-weighted sound pressure level

Table 4. *p* values for comparisons of hearing protectors' selection results obtained by the OB, HML and SNR methods.

Type of noise	Type of hearing protectors	*p* OB vs HML	*p* OB vs SNR	*p* HML vs SNR
Noise type 1	Earmuffs	0.866	0.808	0.944
	Earplugs	0.813	0.447	0.607
Noise type 2	Earmuffs	0.012*	0.039*	0.617
	Earplugs	0.003*	0.029*	0.394
Noise type 3	Earmuffs	0.591	0.785	0.430
	Earplugs	0.651	0.962	0.689
Noise type 4	Earmuffs	0.524	0.917	0.582
	Earplugs	0.394	0.066	0.347
High-frequency noise (Standard No. ISO 4869-2:2018 [21])	Earmuffs	0.862	0.555	0.457
	Earplugs	0.898	0.751	0.677
Low-frequency noise (Standard No. ISO 4869-2:2018 [21])	Earmuffs	0.749	0.946	0.685
	Earplugs	0.930	0.117	0.141

*$p < 0.05$.
Note: OB = octave band.

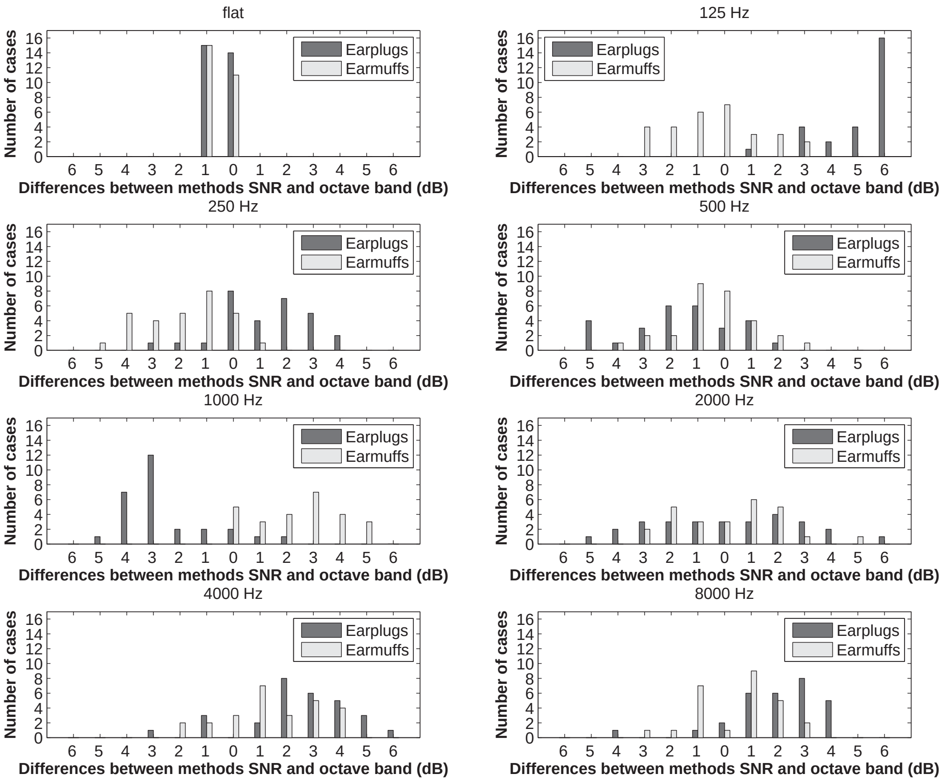

Figure 16. Number of hearing protectors for which there is a difference between the *A*-weighted sound pressure level under those hearing protectors as determined by the HML and octave band methods.

under those hearing protectors as determined by the HML and OB methods (Figure 16) and the SNR and OB methods (Figure 17). If the sound pressure level of the noise is the same over the entire frequency range ('flat' marking), there is a small discrepancy between the selection results obtained using different methods. Both when comparing the HML method with the OB method as well as comparing the SNR and OB methods, in almost all cases there is full compliance of the selection results or the difference is not greater than 1 dB. This is different when a component with a higher sound pressure level is included in one of the frequency bands of noise, which will dominate

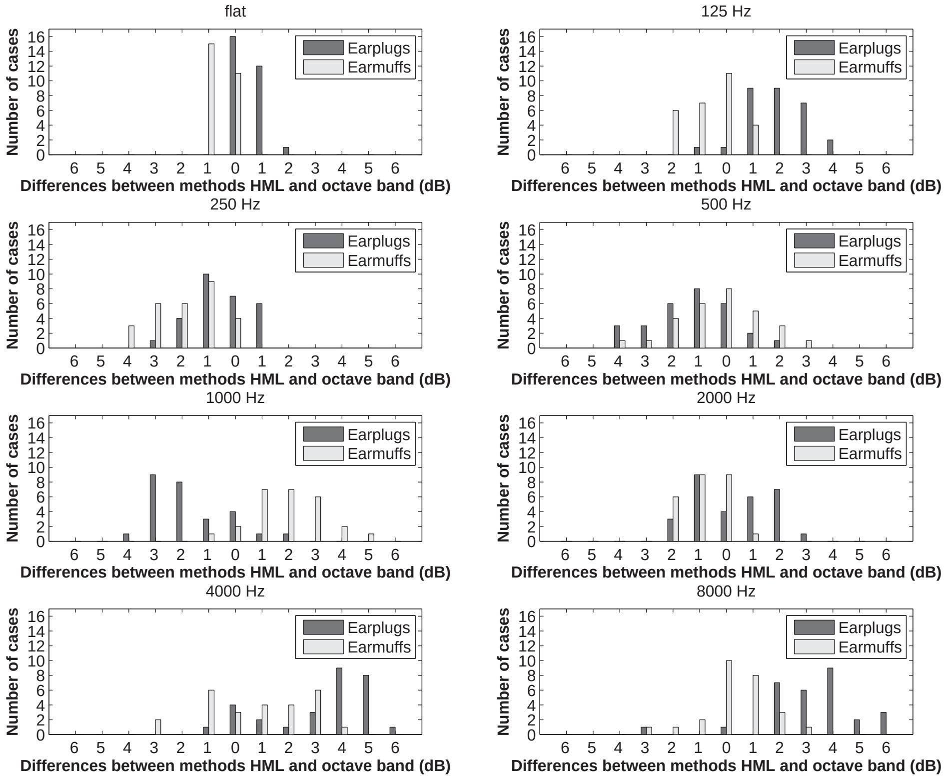

Figure 17. Number of hearing protectors for which there is a difference between the *A*-weighted sound pressure level under those hearing protectors as determined by the SNR and octave band methods.

the level in the other frequency bands. The inclusion of this component into the noise makes the graphs shown in Figures 16 and 17 less slender and the differences in the selection result obtained by different methods increase. For example, in a situation in which the noise contains a dominant component in a frequency band of 125 Hz, a difference of up to 4 dB (HML vs OB methods) and 6 dB (SNR vs OB methods) is observed as the selection result. Additionally, for the earplugs, unlike the earmuffs, it is possible to observe a quite significant shift of the bars with results to the right part of the graph. This means that, for earplugs, the HML and SNR methods overestimate the value of the *A*-weighted sound pressure level under those earplugs. For most earmuffs, the inclusion of a dominant component in a frequency band of 125 Hz results in discrepancies resulting from the selection. There are cases of both overestimation and underestimation of the *A*-weighted sound pressure level. At the same time, in approximately 1/3 and 1/4 of the cases of earmuffs, the result of the selection using HML and OB methods, as well as SNR and OB methods, is convergent. In all cases, the inclusion of the dominant component of the noise in the 250-Hz frequency band results in a shift of the result bars to the left in relation to the previously discussed situation. The selection of the HML and SNR methods causes an underestimation of the *A*-weighted sound pressure level under the earmuffs. This underestimation of the *A*-weighted sound pressure level may be as much as 4 dB (HML method) and 5 dB (SNR method). For earplugs, use of the HML method does not significantly affect the result of the selection. In most cases, the difference between the *A*-weighted sound pressure level obtained by the HML and OB methods is not greater than 1 dB. This is different for the SNR method, where the result of the selection for most earplugs is overestimated, as was the case with the aforementioned dominant component in the 125-Hz frequency band. The inclusion of the dominant component of the noise in the 500-Hz frequency band indicates that both for the HML and SNR methods and for the earmuffs and earplugs there is overestimation and underestimation of the value of the *A*-weighted sound pressure level under the hearing protectors. The highest discrepancy of the selection result of 5 dB occurred with the SNR method. Quite large differences between the earmuffs and the earplugs regarding the number of individual differences in the selection results are observed when there is a dominant component in the 1000-Hz frequency band. For the earmuffs, the *A*-weighted sound pressure level value is overestimated when the selection was performed using both the HML and the SNR method. However, for the earplugs, the opposite is true. With most of the earplugs, there is an underestimation in the selection result. This is the opposite of the situation that occurs when analysing the 125-Hz frequency band. The likely cause of the substantial differences between the earmuffs and earplugs for both frequencies is due to a meaningful difference in the sound attenuation occurring for those frequencies between

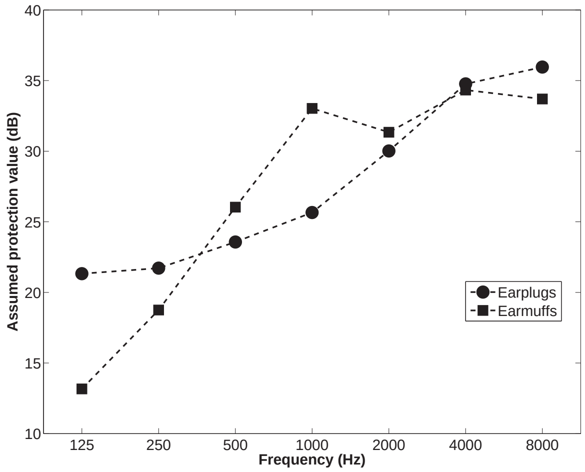

Figure 18. Average assumed protection value calculated for all earmuffs and earplugs included in the selection.

the earmuffs and the earplugs. Figure 18 presents the average assumed protection value (sound attenuation of the hearing protector decreased by the value of standard deviation) calculated for all earmuffs and earplugs considered in the analysis. In this figure, differences in attenuation as large as about 7 dB are observed only for frequencies of 125 and 1000 Hz. For the remaining frequencies, these differences do not exceed 3 dB.

The impact of including a dominant component of the noise in the 2000-Hz frequency band is lower for the HML method than for the SNR method. The selection result for most hearing protectors when carried out using the HML method does not differ by more than 2 dB compared to the reference OB method. This is different when the SNR and OB methods are compared. This difference in selection may be up to 6 dB. For both the HML and SNR methods, overestimation and underestimation of the selection results are observed. The inclusion of a dominant component of the noise in the 4000 and 8000-Hz frequency bands causes the result of the selection to be overestimated for a large number of hearing protectors. This is shown mainly in earplugs, for which this overestimation may amount to up to 6 dB.

4. Summary

The noise type is of great importance for the accuracy of selection of hearing protectors. In the case of noise present in real conditions and characterized by the presence of dominant frequency components, the result of the selection carried out using the HML and SNR methods differs from the result of the selection carried out using the OB method. For earmuffs, the differences in the selection result reach 7 dB, whereas for earplugs they even reach up to 9 dB.

The result of selection using the HML and SNR methods can be both underestimated and overestimated, compared to the reference OB method. This means that hearing protectors may be used despite insufficient protection or may be rejected even though they provide sufficient protection. For noise with no dominant frequency components, no meaningful differences are observed between the selection results obtained by different methods.

Similar conclusions can be drawn from the analysis of the results of the selection of hearing protectors for simulated noises. No significant influence of the selection method on the selection result is observed when the sound pressure level of noise is uniform. The inclusion of dominant components results in discrepancies between the selection results, reaching up to 6 dB. Due to the various characteristics of the sound attenuation of earmuffs and earplugs, there is a different impact of the method on the result of the selection for both types of hearing protectors. For example, the occurrence of a dominant component in the noise in a frequency band of 125 Hz causes an underestimation of the selection result for earmuffs and an overestimation for earplugs. However, for the 1000-Hz frequency band, the situation is the opposite. The occurrence of underestimation of the selection result, i.e., determination of an insufficient value of the *A*-weighted sound pressure level under the hearing protectors, is so dangerous that it actually means less hearing protection than is indicated by the selection results. When selecting hearing protectors using the HML or SNR methods, it may be presumed that they are properly selected and will protect the hearing of their user. However, when the noise spectrum contains dominant frequency components, although the result of the selection using the HML and SNR methods indicates appropriate hearing protection, this is not necessarily the case.

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No potential conflict of interest was reported by the authors.

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