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ATTENUATING PROPERTIES OF HEARING PROTECTORS IN VERSUS TIME FACTOR

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Abstract. In the noisy environment, workers use hearing protectors to protect their hearing organ against adverse effects of noise. Hearing protectors should be well selected according to the spectrum and level of noise.
The selection of hearing protectors is based on the sound attenuation values measured in laboratory conditions. Workers usually use hearing protectors provided by employers as long as there are no signs of any physical damage. The aim of this study was to assess the effect of use and storage as well as of atmospheric conditions on sound attenuation of ear-muffs. Four models of ear-muffs popular in the Polish work environment were tested for two years. They fulfilled the PN-EN 352-1 standard requirements and were granted a certification mark. Fifteen samples of each model were used by workers every working day; 10 samples were exposed to natural atmospheric conditions; and 10 samples were stored in accordance with the manufacture's advice. Temperature and humidity were checked each day. After periods of one and two years, sound attenuation was measured according to PN-EN 24869-1 standard. The observed changes in high-frequency attenuation value H, medium-frequency attenuation value M, low-frequency attenuation value L and single number rating calculated according to PN - EN ISO 4869-2, are presented. The quantitative assessment how far the period of use, storage and exposure to natural atmospheric conditions affect protection achieved by the four popular models of ear-muffs is presented.

Key words:
Hearing protectors, Ear-muffs, Sound attenuation

INTRODUCTION

Noise at a workplace involves a risk to the health and safety of workers. According to European Council Directive 86/188/EC [1], hearing protectors are used to reduce the risk resulting from the exposure to noise and to protect the workers against noise-induced hearing loss. To be effective, the hearing protectors must be selected after considering the characteristics of noise. Existing methods [2,3] of assessing the A-weighted sound pressure level effective to the ear are based on the measurements of sound attenuation of hearing protectors in the laboratory conditions. In a "real world" situation the effective attenuation of hearing protectors may be significantly lower than that in the laboratory [4,5]. There are several reasons for this fact. In the laboratory, the measurements of sound attenuation are carried out with the participation of trained subjects who are to fit hearing protectors to obtain the best attenuation [6]. The experimenter has to assure a good fit and acoustic seal [7]. In laboratory experiments, performed for certification purposes, a new

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product is tested in standard atmospheric conditions. In the "real world" situation the workers are usually naive in respect to hearing protectors use and they rely only on manufacture's instruction for users [8,9]. Hearing protectors are usually used as long as there are no signs of any physical damage. The lack of signs of damage of hearing protectors does not mean that sound attenuation is not significantly diminished. In Europe, the work environment varies considerably (e.g., the environment of forest workers in North Europe and working conditions of hammer workers on the roads of South Europe). These environmental conditions also affect the rate of changes in the performance of hearing protectors.

Actually, to protect the workers against noise-induced hearing loss by means of hearing protectors, their effective "real world" attenuation must be estimated.

The aim of the work was to assess how far the period of use and storage as well as of exposure to natural atmospheric conditions affect high-frequency attenuation, middle-frequency attenuation, low-frequency attenuation and single number rating (SNR) of ear-muffs. Four models of ear-muffs, of normal size with headband, representative of the Polish work environment, were tested. The models used fulfilled the PN–EN 352-1 standard requirements [10] and were granted a certification mark.

MATERIALS AND METHODS

Brand new, just bought, 35 samples of each model of ear-muffs were tested for two years.

Fifteen samples of each model (marked A1, A2,…., A15) were supplied to 60 workers for their use. Noisy workplaces were chosen at four different industrial companies (two coal mines, a steel mill and a wool factory). The noise at work-stands was measured and A-weighted sound pressure levels under the cup of tested ear-muffs were assessed according to PN-EN ISO 4869-2 standard [11]. The estimated A-weighted sound pressure during the use of hearing protectors ranged from 84 to 70 dB. The workers used the tested ear-muffs every day for two years. The temperature and humidity of air at each work-stand were measured.

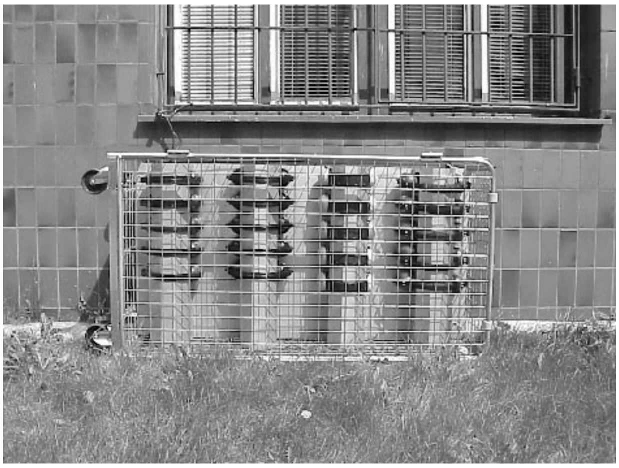

Fig. 1. Ear-muffs exposed to natural atmospheric conditions.

Ten samples of each model of ear-muffs were exposed to natural atmospheric conditions (Fig. 1) 8 h/working day for two years. The samples were mounted on special head simulators. The temperature and humidity of the air were controlled twice a day. During the other 16 h, the samples were stored in accordance with the manufacturer's instructions.

The remaining ten samples of each tested model of ear-muffs were stored for two years in clean, dry, uncontaminated environment according to the manufacture's recommendations.

After one year and then after two years of use and exposure to atmospheric conditions, the six samples of each model of ear-muffs, taken at random, were tested at the laboratory conditions. The sound attenuation and headband force of ear-muffs were measured. The measurements of sound attenuation were performed with 16 subjects in accordance with PN-EN 24869-1 standard. The stored samples were tested after two years. The high-frequency attenuation value H, medium-frequency attenuation value M, low-frequency attenuation value L and SNR of hearing protectors were determined according to PN-EN ISO 4869-2 standard, based on the measured values of sound attenuation. For each calculated values, H, M, L and SNR uncertainties were calculated at 95% confidence interval [12].

RESULTS AND DISCUSSION

Figure 2 shows the differences between the estimated attenuation data of H, M, L and SNR of hearing protectors

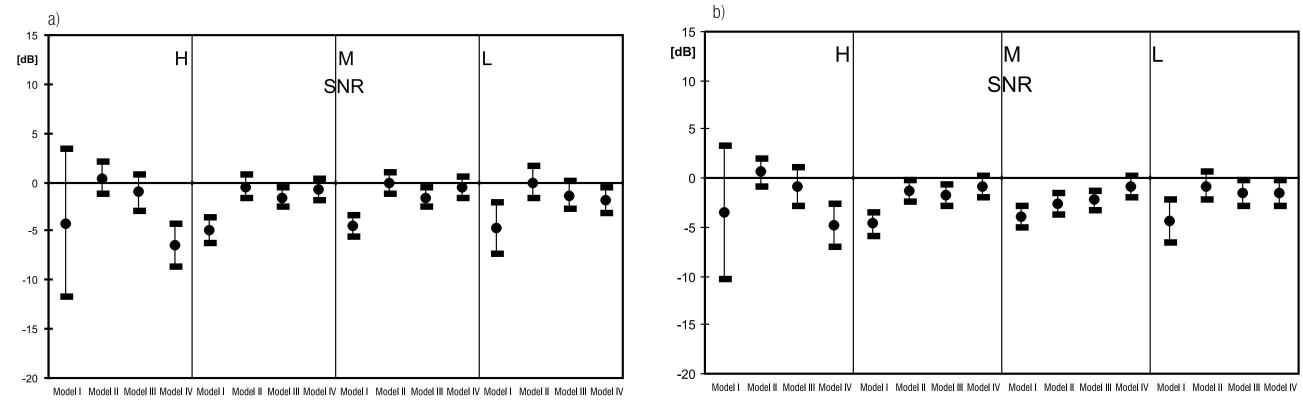

Fig. 2. Changes in attenuation (H, M, L and SNR) of ear-muffs; (a) after a one-year use, (b) after a two-year use.

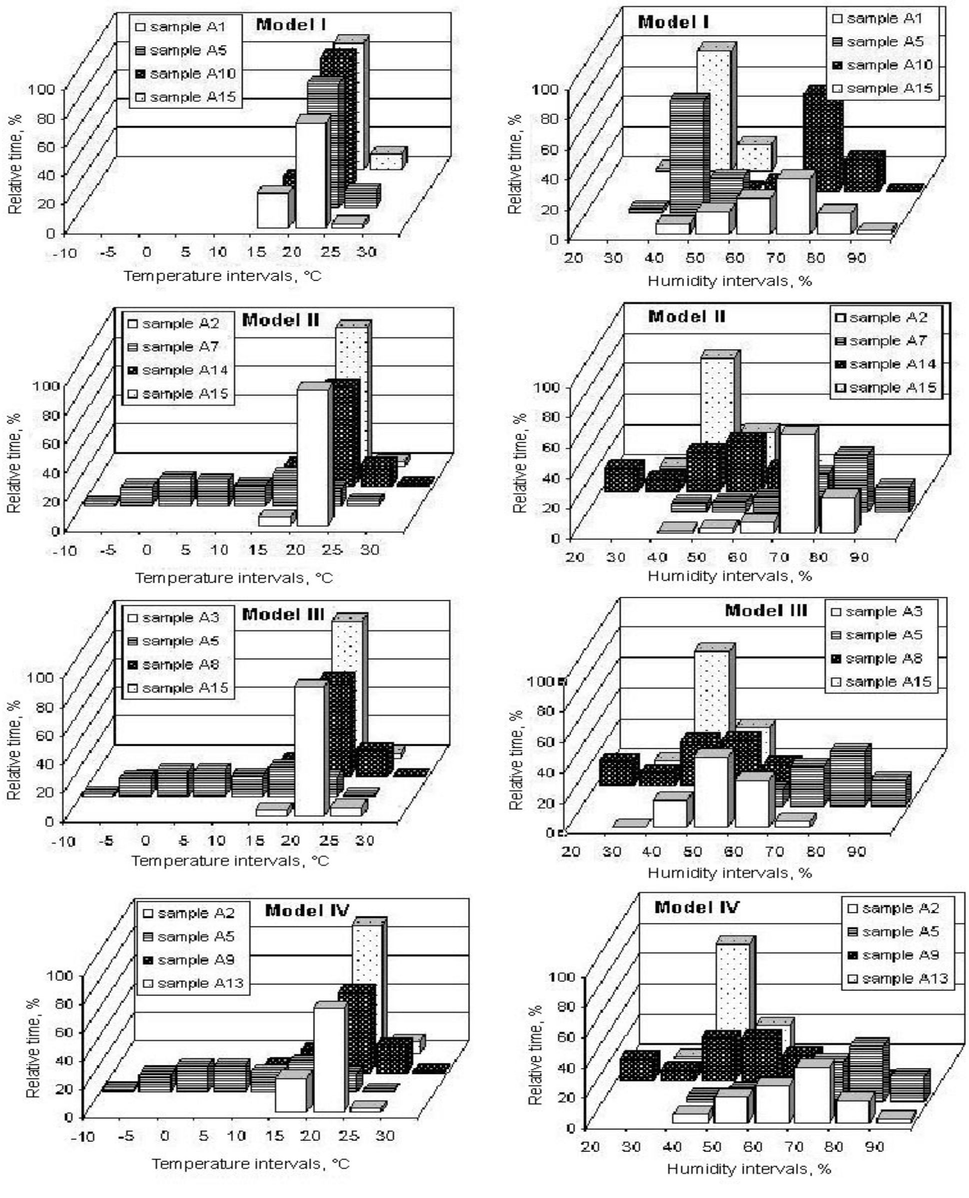

Fig. 3. Histograms of temperature and humidity of air at work-stands where the tested samples of ear-muffs were used for two years.

after using them for one and two years and the values given in the manufacturer's instruction for users.

Figure 3 presents the histograms of temperature and humidity of air at work-stands where the tested samples of ear-muffs were used for two years; they include data on: (a) samples of model I, (b) samples of model II, (c) samples of model III, (d) samples of model IV.

The most stable atmospheric conditions were observed at work-stands where samples of model I were tested. Nevertheless, after a one-year use all the estimated attenuation values of model I were significantly lower (about 4 dB on average) than those given in the manufacturer's instruction. There were very similar atmospheric conditions at work-stands where models II, III and IV were tested. The significant decrease in the attenuation value was observed in model IV after the first year of use; estimated high-frequency attenuation value H was by 6.4 dB lower than that given in the information for the user. The second year of using ear-muffs of models I and IV did not affect significantly attenuation of tested samples. Much smaller changes were observed for model III; the estimated attenuation values were lower by no more than 2.3 dB. The attenuation values of model II were stable during a two-year use.

Figure 4 presents the differences between the estimated attenuation data of H, M, L and SNR of hearing protectors after one- and two-year exposures to changing, natural atmospheric conditions and the values given in the manufacturer's instruction for users.

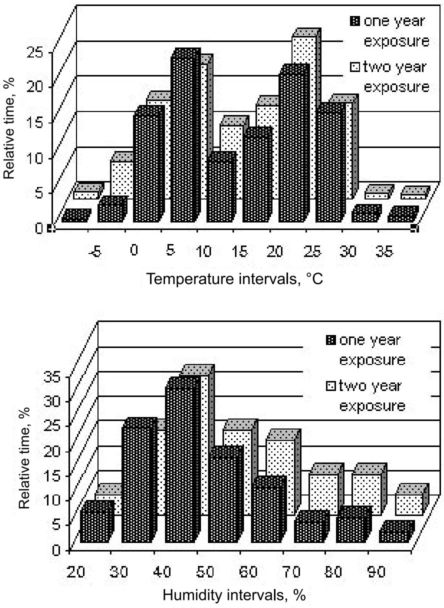

Fig. 5. Histograms of temperature and humidity of the air in the environment where the tested samples of ear-muffs were exposed for one and two years; (a) temperature data, (b) humidity data.

Figure 5 shows the histograms of temperature and humidity of the air in the environment where the tested samples of ear-muffs were exposed for one and two years; (a) temperature data, (b) humidity data.

The natural atmospheric conditions affected mostly the attenuation values of ear-muffs of model I. After the first year of exposure, the maximum decrease was observed regarding the manufacturer's data for medium-frequency attenuation M – 4.8 dB. After two years of exposure attenuation M decreased by 9.2 dB. Significant changes were also observed in model IV after one year of exposure; the

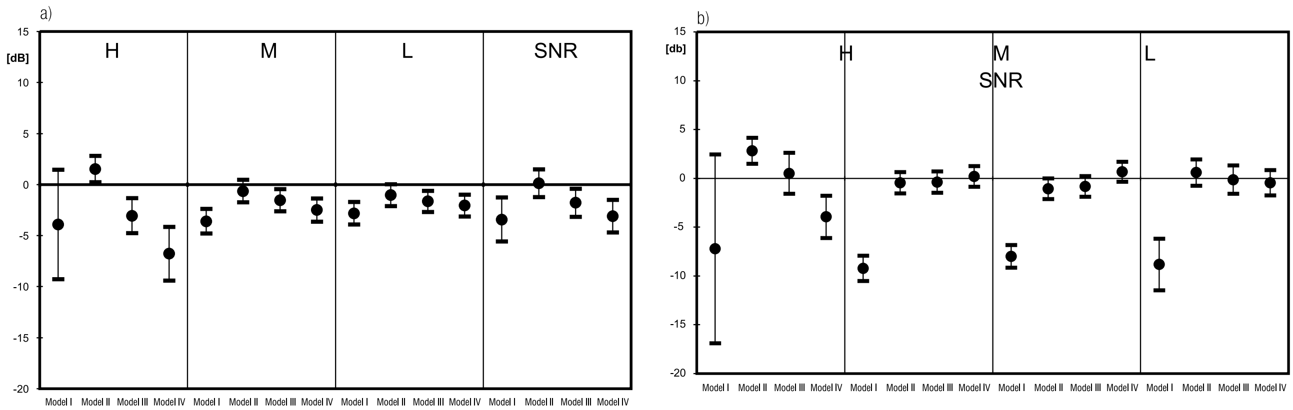

Fig. 4. Changes in attenuation (H, M, L and SNR) of ear-muffs exposed to natural atmospheric conditions; (a) after a one-year exposure, (b) after a two-year exposure.

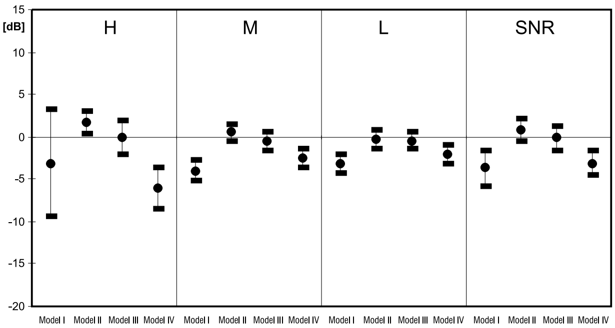

Fig. 6. Changes in attenuation (H, M, L and SNR) of ear-muffs due to a two-year storage.

estimated high attenuation value was by 6.4 dB lower than that given in the manufacturer's information. The influence of natural atmospheric conditions on the attenuation of ear-muffs of models II and III was rather small.

Figure 6 presents the differences between estimated attenuation data on H, M, L and SNR of hearing protectors after a two-year storage and the values given in the instructions for users.

A two-year storage did not affect attenuation of hearing protectors of models II and III. A significant influence was observed in modes I and IV. The attenuation values of model I were lower than the manufacturer's data by about 4 dB on average. In model IV, the high-frequency attenuation decreased by 6.1 dB.

CONCLUSIONS

The use, storage and exposure to natural atmospheric conditions of four models of ear-muffs for one and two years revealed that the changes in high-frequency attenuation H, medium-frequency attenuation M, low-frequency attenuation L and SNR may be significant even if there is no signs of damage of hearing protectors.

The differences observed between the attenuation values (H, M, L and SNR) after one or two years of use, storage and exposure of ear-muffs to natural, atmospheric conditions, and manufacture data supplied to users vary between products. The highest value of the decrease, 9.2 dB, in the medium-frequency attenuation M respective to the manufacture data was observed for model I after two years of exposure to natural atmospheric conditions.

The results of the study indicate the need to continue more extensive research in this field.

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REFERENCES

1. *Council Directive of 12 May 1986 on the protection of workers from the risks related to exposure to noise at work* (86/188/EEC). Off. J. Eur. Communities, 1986; No L 137: 28-34.
2. Standard PN-EN 458:1993. *Hearing protectors – Recommendations for selection, use, care and maintenance – Guidance document*. Warsaw: Polish Committee for Standardization; 1999 [in Polish].
3. Kotarbińska E. *Ear-muffs as a preventive measure in occupational hearing impairment.* Med Pr 2000; 2: 185–96 [in Polish].
4. Kotarbińska E, Mnich J. *Changes in protection properties of hearing protectors due to duration of use – preliminary investigations.* Proceedings of the Open Seminar on Acoustics; 2000 Sept 19–22; Rzeszów – Jawor, Poland. Rzeszów, Poland: Polish Acoustical Society; 2000. p. 475–80.
5. Kotarbińska E, Mnich J. *Investigations of changes in acoustical properties of hearing protectors due to time.* Proceedings of the12th International Conference on Noise Control. 2001 Sept 24–26; Kielce, Poland. Warsaw: Central Institute for Labour Protection and Department of Mechanics and Vibroacoustics of the University of Mining and Metalurgy; 2001. p. 411–7.
6. Standard PN-EN 24869-1: *Acoustics – Hearing protectors – Subjective method for the measurement of sound attenuation.* Warsaw: Polish Committee for Standardization; 1999 [in Polish].
7. BergerE H, Franks JR, Behar A, Casali JG, Dixon–Ernst C, Kieper RW. *Development of a new standard laboratory protocol for estimating the field attenuation of hearing protection devices. Part III. The validity of using subject-fit data.* JASA 1998; 1–2: 665–72.
8. Franks JR, Murphy WJ. *Repeatability and reproducibility in hearing protector testing.* J Acoust Soc Am 1996; 4: 2464.
9. Martin A. *How realistic are standard subjective test methods for evaluating hearing protector attenuation.* In: Alberti PW, editor. *Per-*

sonal Hearing Protection in Industry. 2nd ed. New York: Raven Press Books Ltd.; 1982. p. 273–98.

10. Standard PN-EN 352-1. *Hearing protectors – Safety requirements and testing – Part 1: Ear-muffs.* Brussels: European Committee for Standardization; 1995.
11. Standard PN-EN ISO 4869-2. *Acoustics – Hearing protectors – Part 2; Estimation of effective A-weighted sound pressure levels when hearing protectors are worn.* Warsaw: Polish Committee for Standardization; 1996 [in Polish].
12. Laitinen H. *Uncertainty in harmonized standards.* [Master thesis]. Vantaa: Helsinki University of Technology; 1988.