



Verifying the attenuation of earplugs in an auto parts factory in China

Wei Gong¹

National Institute for Occupational Safety and Health (NIOSH), Centers for Disease Control and Prevention (CDC), Cincinnati, Ohio, USA; Jiangsu Provincial Center for Disease Control and Prevention, Jiangsu, China

Thais C. Morata²

National Institute for Occupational Safety and Health (NIOSH), Centers for Disease Control and Prevention (CDC), 1090 Tusculum Avenue, Cincinnati OH, 45226, United States

ABSTRACT

This study compared methods used to predict the attenuation of earplugs with the results from objective attenuation measurements. Personal noise measurement and earplug fit-tests were performed on 385 workers from an auto parts factory. All participants used one type of pre-molded earplugs. 78.2% of workers had L_{Aeq8h} above 85 dB(A). The mean Personal Attenuation Ratings (PAR) was 7 dB (median 5 dB, SD 7.2 dB), well below the earplug's single number rating (SNR) of 25 dB and de-rated SNR (15 dB). No PAR increment was detected with increasing L_{Aeq8h} ($F = 0.657$, $p = 0.709$). Neither the noise attenuation rating (indicated in the product's label) nor the de-rated value predicted the level of hearing protection device attenuation obtained by the workers who were wearing earplugs. Objective measurements of earplug attenuation could improve the effectiveness of hearing conservation programs.

1. INTRODUCTION

Noise has become an increasingly prevalent occupational hazard with China's rapid economic development. In November 2007, China issued a legally enforceable occupational exposure limit (OEL) of 85 dBA over an 8-hour working day with a 3-dB exchange rate ^[1] Chinese workers were required to wear hearing protection devices (HPDs) if they were occupationally exposed to noise levels at or above the OEL.^[2] In China, HPDs are required to be labelled by the manufacturer with a Single Number Rating (SNR).^[3] To account for differences between attenuation under laboratory versus real-world conditions, the Chinese National Standard for Hearing Protection for

¹ wrm3@cdc.gov

² tmorata@cdc.gov

Workers in Industrial Enterprises ^[4] required that the SNR should be de-rated by 40% when determining whether worker noise exposure has been sufficiently reduced by the device.

By using an objective method to verify the performance of HPDs (individual fit-testing) several studies have shown that the SNR listed on the HPD label bears little resemblance to the actual attenuation obtained by users in the real world ^[5-8]. The objective of this field study was to evaluate the predicted attenuation of both SNR and de-rated SNR and the individual fit-testing PARs among earplug users in Chinese manufacturing plants

2. PARTICIPANTS AND METHODS

2.1. Selection of participants and background information about the surveyed factory

The study was conducted in an auto parts factory located in Jiangsu province, eastern China, in August 2018. A total of 385 workers were selected from an original pool of 504. The inclusion criteria were: (1) no history of prior employment in a high noise environment; (2) no military service history or shooting activities; (3) a minimum of 1 year of employment at the current job; (4) a clear view of the tympanic membrane on otoscopic examination; (5) type A tympanogram. The production area of the surveyed factory consisted of two separated one-story buildings; each building had multiple production lines. Processing consisted of tube cutting, grinding, machining and inspections. There were no physical barriers/walls between lines. The factory operated with three rotating shifts Monday through Friday, 8 hours per shift.

2.2. Questionnaire survey

Each worker was required to complete a health questionnaire, which was administered through a face-to-face interview for quality control. The following information was collected: demographic information (age, gender, etc.), noise exposure history (factory, work title, length of employment, duration of daily noise exposure, and history of hearing protector device (HPD) use); personal life habits (e.g., shooting, smoking and drinking); and history of ear disease and use of ototoxic drugs.

2.3. HPD Fit testing

Each worker was required to use one type of pre-molded earplugs with SNR= 25 dB. The HPD fit-testing system used in this study was the 3MTM E-A-RfitTM Dual Ear Validation System. ^[9] The fit testing was performed in a conference room at the local hospital. The personal attenuation rating (PAR) was obtained when the worker fit the surrogate probed test earplugs by himself or herself. The PAR passing criterion was defined as being greater than the target minimum attenuation, which was based on the individual noise exposure results (see section 2.4). This was set as the difference between the employee exposure and the permissible exposure limit, which in China is 85 dBA for 8 hours.

2.4. Personal noise exposure levels

Workers wore a digital recorder (Aihua, Model AWA5610B, Hangzhou, China), operating continuously with 16-bit resolution at a 48 kHz sampling rate, during their 8-hour shifts. The

dosimeter microphone was placed on the employees' shoulder at the midpoint between the neck and the edge of the shoulder. Each dosimeter was calibrated before and after the measurement using a Model AWA6221 Sound Level Calibrator (Aihua Instruments, Hangzhou, China). The equivalent continuous A-weighted sound pressure level over 8 hours ($L_{Aeq,8h}$) was calculated based on the individual full-shift noise recording data with NIOSH recommendations for workplace noise exposure sampling. ^[10]

2.5. Data analysis

Statistical analyses were performed with SAS® (Release 9.4, SAS Institute, Inc., Cary, North Carolina). The correlation between PAR and $L_{Aeq,8h}$ was examined by using the Pearson correlation coefficient. An analysis of variance (ANOVA) test was conducted for the difference of mean PAR by $L_{Aeq,8h}$ group.

3. RESULTS

3.1. Participant characteristics

Seventy percent of the participants were male ($n = 270$) and 30% were female ($n = 115$). Their ages ranged from 22 to 50 years with a median of 37 years. Thirty-two percent of workers ($n = 123$) had been employed for 1-5 years. Sixty-eight percent of workers ($n = 265$) had 6-15 years of work experience. The median duration of noise exposure was 7.8 years (25th-75th percentile: 4-11 years).

3.2. Noise exposure levels

The average individual noise exposure level in the auto parts factory was 87 dBA, ranging from 77 dBA to 102 dBA, with a standard deviation (SD) of 3.5 dBA. The $L_{Aeq,8h}$ estimates for 78.2 % of the workers ($n = 301$) exceeded 85 dBA. The highest noise was generated by the tube cutting, grinding and machining processes. Figure 1 shows thirty-seven percent ($n = 143$) of workers had an $L_{Aeq,8h}$ of 85 to 87 dBA, and 31.9 % ($n = 123$) were exposed to noise from 88-93 dBA.

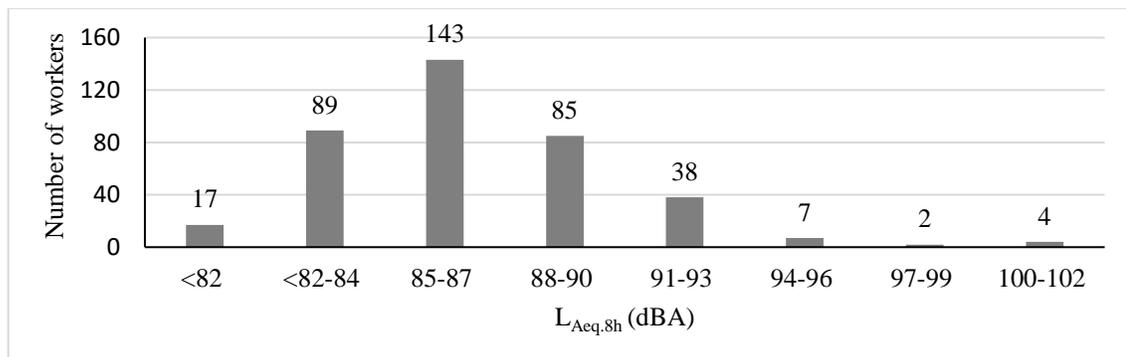


Figure 1. Noise exposure ($L_{Aeq,8h}$) distribution among workers. The mean $L_{Aeq,8h}$ was 87 dBA, ranging from to 78-102 dBA.

3.3. Personal attenuation rating

In China, a 40% derating of the SNR is required in the workplace, which reduces the expected

attenuation for the earplug used in this study from 25 to 15 dB. Figure 2 reveals that the lowest personal attenuation rating (PAR) was 0 dB and the highest was 26 dB; the mean PAR was 7 dB (median was 5 dB). As worn by the study participants, the earplugs did not provide any noise attenuation for 37% (n = 149) of the workers. The mean PAR (7 dB) was well below the labelled SNR (25 dB) and de-rated SNR (15 dB). Eighty out of 385 tested workers achieved the de-rated SNR, including one worker that achieved the labelled SNR. The PAR passing rate was 54% among 315 workers whose noise exposure levels were 85 dBA or above.

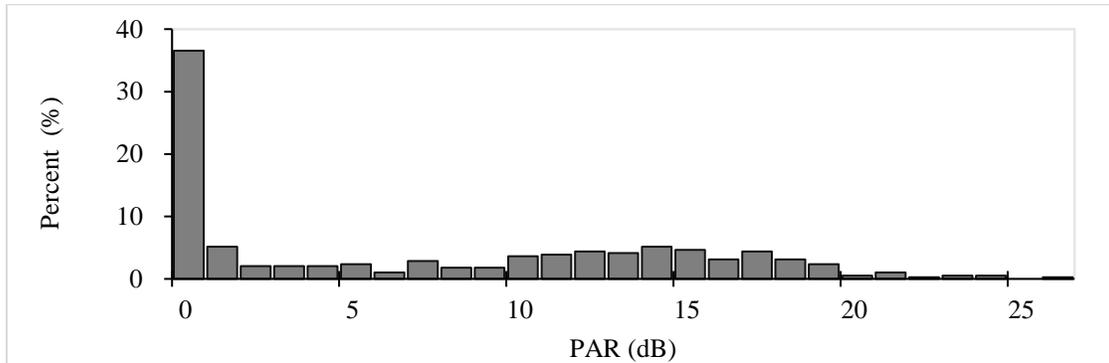


Figure 2. Histogram showing the percentage of workers (n=385) by the personal attenuation rating (PAR) they achieved in this study.

The Pearson correlation between PAR and $L_{Aeq,8h}$ is -0.03233 ($p = 0.394$). This indicates a slight negative linear relationship between PAR and $L_{Aeq,8h}$ but was not significant. Analysis of variance (ANOVA) shows that there was no difference in the mean PAR among $L_{Aeq,8h}$ groups ($F = 0.657$, $p = 0.709$), as shown in Figure 3.

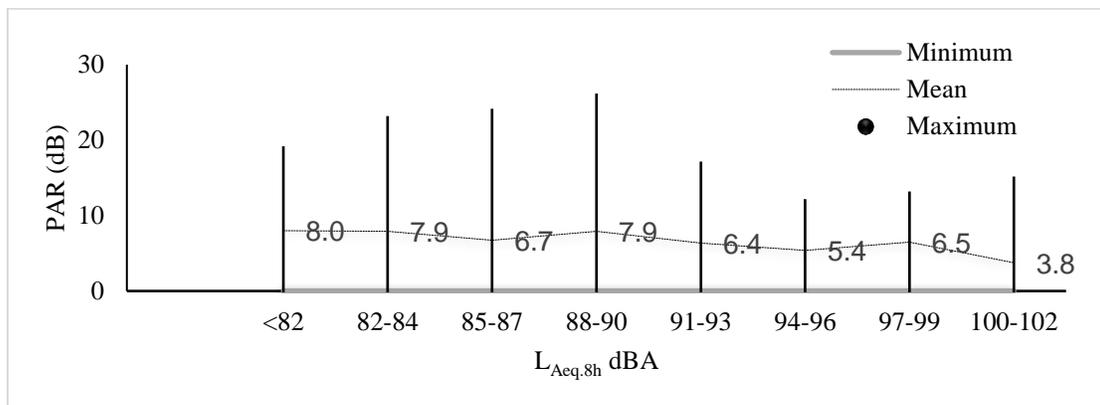


Figure 3. PAR ranges by $L_{Aeq,8h}$ group. The dashed line in this figure represents the mean PAR at each $L_{Aeq,8h}$ group. There is no significant difference in the mean PARs among noise exposure groups.

4. DISCUSSION

The main objective of this study was to determine whether the SNR or the derated SNR could predict PARs at a real workplace. Study results revealed a wide range of attenuation from 0 dB to 25 dB with a median of 5 dB. The mean PAR was 7 dB, which is similar to the results obtained in a previous investigation with the same type of pre-molded earplug ^[11]. Only one of 385 tested workers achieved the labelled SNR for the earplug used in this study. Eighty of 385 workers (21%) met the 40% derating value of the SNR used in China, while the actual attenuation value obtained by more than half of the workers was less than or equal to 5 dB. Similar results had been reported previously ^[11, 12]. Those findings reconfirmed that the neither the labelled SNR nor China's derating requirement are likely to provide an accurate prediction of individual PARs obtained in the field. The SNR and the derating scheme both overestimate the real protection for individual workers at the workplace.

Only 54% of the workers achieved the necessary PAR, which means that 46% of the workers exposed to 85 dBA or above were underprotected. These findings show that the effectiveness of earplugs to protect workers from hazardous noise exposures and the risk of NIHL is insufficient in this auto parts factory. Additionally, observations conducted during the investigation revealed that several workers rarely wear earplugs all the time during their full shift even though they were required to do so. Some workers took the earplugs off when they needed to communicate and some workers dropped their earplugs during the shifts without noticing it. Néglise ^[13] tested various types of earmuffs and one type of pre-molded earplug in 24 workers from 8 different companies. During shifts, workers had their earplugs regularly removed and poorly inserted, and the PAR data showed considerable fluctuations over entire work shift.

A limitation of the present study is that PARs were tested only once, before the workers' audiological testing. It is possible that the workers insert earplugs differently or fit them better than how they do it during regular workdays, because they realized that they were being tested. Therefore, the noise attenuation provided by the earplugs worn by the workers in the actual working environment is different than that of the study participants in the test situation.

Finally, no PAR increment was detected with increasing noise exposure levels. This finding was different than previously reported by Chen et al ^[14] and Leensen et al ^[15]. It was reported that workers in areas with a higher noise exposure level might be more bothered by noise and consequently be more conscious about the use of HPD. In our study, workers exposed to noise at higher levels did not obtain higher PARs.

5. CONCLUSIONS

This study suggests that in current practice, neither the noise attenuation rating (indicated in the product's label) nor the de-rated value predicted the level of hearing protection device attenuation obtained by the workers at an auto parts factory. Workers who are not trained in the proper technique for insertion of ear plugs obtain little attenuation. The combination of low PARs and ineffective HPD usage in the workplace should be a subject of concern at all hazardous noise workplaces. Objective measurements of earplug attenuation could identify workers at risk to be over exposed to hazard noise and improve the effectiveness of hearing conservation programs.

6. ACKNOWLEDGEMENTS

We gratefully acknowledge the participants in the auto part factory, and all who contributed to the data collection. The authors also thank Dr. Wei Qiu from the State University of New York for noise data analysis, and Ms. Amy Feng and Dr. Edward Krieg from the U.S. National Institute for Occupational Safety and Health for the fit test data analysis.

7. DISCLAIMER

The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention. Mention of any company or product does not constitute endorsement by the National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention.

8. REFERENCES

- [1] GBZ, Chinese National Occupational Health Standard, "Occupational exposure limits for hazards agents in the workplace Part2: Physical agents (GBZ 2.2-2007)," *National Health and Family Planning Commission of the People's Republic of China*. Beijing, China: 2007.
- [2] GBZ, Chinese National Occupational Health Standard, "Hygienic Standards for the Design of Industrial Enterprises (GBZ 1-2010)." *National Health and Family Planning Commission of the People's Republic of China*. Beijing, China: 2010.
- [3] GB/T, Chinese national standard, "Guideline for selection of hearing protectors (GB/T 23466-2009)." *Administration of Quality Supervision, Inspection and Quarantine of People's Republic of China; Standardization Administration of China*. Beijing, China: 2009.
- [4] NHPC, National Health and Family Planning Commission of the People's Republic of China, "Standards for hearing protection for workers in industrial enterprises (in Chinese)," *National Health and Family Planning Commission of the People's Republic of China*. Beijing, China: NHPC. 1999.
- [5] Royster, L.a.R., J., "An Overview of Hearing Conservation Practices in the USA," *J. Acoust. Soc. Am.*, 105(2, Pt. 2), 1009.
- [6] Murphy, W.J., C.L. Themann, and T.K. Murata, "Hearing protector fit testing with off-shore oil-rig inspectors in Louisiana and Texas," *Int J Audiol*, 2016. 55(11): p. 688-98.
- [7] Berger, E.H., et al., "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," *J Acoust Soc Am*, 1998. 103(2): p. 665-72.
- [8] Trompette, N., Kusy, A., "Suitability of Commercially Available Systems for Individual Fit Tests of Hearing Protectors," *INTER-NOISE 2013*.

- [9] Gong, W., et al., "Evaluating the effect of training along with fit testing on foam earplug users in four factories in China." *Int J Audiol*, 2019. 58(5): p. 269-277.
- [10] NIOSH, National Institute for Occupational Safety and Health, "Criteria for a Recommended Standard Occupational Noise Exposure." *National Institute for Occupational Safety and Health* 1998.
- [11] Liu, Y., et al., "Evaluating the effect of training along with fit testing on pre-molded earplug users in a Chinese petrochemical plant," ePublish Ahead of Print.
- [12] Franks, J.R., et al., "Four earplugs in search of a rating system." *Ear Hear*, 2000. 21(3): p. 218-26.
- [13] Nelisse, H., et al., "Measurement of hearing protection devices performance in the workplace during full-shift working operations," *Ann Occup Hyg*, 2012. 56(2): p. 221-32.
- [14] Chen, Y., et al., "Prevalence and determinants of noise-induced hearing loss among workers in the automotive industry in China: A pilot study," *J Occup Health*, 2019. 61(5): p. 387-397.
- [15] Leensen, M.C., J.C. van Duivenbooden, and W.A. Dreschler, "A retrospective analysis of noise-induced hearing loss in the Dutch construction industry," *Int Arch Occup Environ Health*, 2011. 84(5): p. 577-90.