Extrapolation of Experimental Field Study to a National Occupational Noise Exposure Standard

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ABSTRACT

Proposing a Noise Standards should be considered seriously by the governmental authorities because of the prevalence of hazardous noise exposure and the seriousness of the effects. In a survey founded by World Health Organization’s regional office in Iran, the existing as well as gathered data from field were applied to propose a National Occupational Noise Exposure Limit. The collected data plus the existing data were processed to: propose a national occupational noise exposure limit and depict the major restrictions in application of existing field data in proposing a national occupational noise exposure limit. Results obtained from the present study shows that the occupational noise levels of 90 to 95 dBA can lead to hearing losses greater than 25 dBA. It was shown that occupational noise levels of 85 to 90 dBA would not lead to hearing losses greater than 20 dBA. The comparison of hearing losses shows that the noise levels of less than 80 dBA will not lead to any significant hearing loss. It was deduced that 85 dBA can be recommended for a national occupational noise limit in Iran. The study also showed that the application of existing field data to recommend a national occupational noise standard may have some restrictions.

Keywords: Occupational Noise, PEL (Permissible Exposure Limit), Field Data, Hearing Loss, Noise Standard, Iran

INTRODUCTION

Occupational noise is a major problem for Iranian industries. Besides causing stress and anxiety, arousing the nervous system, and lowering work performance, hazardous noise can cause temporary and permanent hearing loss [1, 2]. Noise-induced hearing loss (NIHL) from long-term noise exposure is a permanent and irreversible hearing loss due to damaged or destroyed inner ear hair cells. Further, the hearing loss worsens due to continued hazardous noise [3].

Noise has long been recognized as one of the most prevalent workplace hazards. In 1988 it was identified by NIOSH as one of the 10 leading occupational problems. According to the existing data, in Iran, more than 2 million workers are exposed to potentially hazardous levels of noise in manufacturing and utilities. Hazardous levels of noise are defined here as time-weighted average levels of 85 dBA and above, although it is well known that some more susceptible workers will incur hearing losses at levels below 85 dBA. In Iran, an additional 1 million agricultural, construction, oil and gas workers are expected to be exposed to these noise levels.

Because of the prevalence of hazardous noise exposure and the seriousness of the effects, proposing the Noise Standards should be considered seriously by
the governmental authorities. A national strategy for the prevention of Noise–Induced Hearing Loss should be proposed to list noise enforcement as a top priority in short–term and long–term objectives for regulations.

In recent years, European, Canadian and other foreign governments have improved and modernized their noise standards where as Iran has maintained the status quo. Such as other countries Iran needs to incorporate procedures such as regulating specific industries and processes for noise labeling noisy machinery, issuing separate standards for newly constructed work places, and devising instructions for the purchase of quiet equipment.

Risk assessment is the main basis for the exposure [4, 5]. Risk assessment can be estimated in various methods. The selection of an exposure limit depends on the definitions of two parameters:

1. The maximum acceptable occupational hearing loss (i.e., the fence)
2. The percentage of the occupational noise-exposed population for which the maximum acceptable occupational hearing loss will be tolerated.

The most common protection goal is the preservation of hearing for speech discrimination. Using this protection goal, NIOSH employed the term "hearing impairment" to define its criteria for maximum acceptable hearing [6]. OSHA later used the slightly modified term "material hearing impairment" to define the same [7]. In this context, a worker was considered to have a material hearing impairment when his or her average HTL for both ears exceeded 25 dB at the audiometric frequencies of 1000, 2000, and 3000 Hz (denoted here as the "1-2-3-kHz definition").

NIOSH assessed the excess risk of material hearing impairment as a function of levels and durations (e.g., 40-year working lifetime) of occupational noise exposure. Thus, for a 40-year lifetime exposure in the workplace to average daily noise levels of 80, 85, or 90 dBA, the excess risk of material hearing impairment was estimated to be 3%, 16%, or 29%, respectively. Based on this risk assessment, NIOSH recommended an 8-hr TWA exposure limit of 85 [6].

Some authors found that the audiometric average of 1000, 2000, 3000, and 4000 Hz provided "a superior prediction of hearing disability in terms of specificity, sensitivity, and overall accuracy." The ASHA Task Force definition is also referred to as the 1-2-3-4-kHz definition in this criteria document. In present study the same method was used.

NIOSH defines material hearing impairment as an average of the HTLs for both ears that exceeds 25 dB at 1000, 2000, 3000 and 4000 Hz. Based on this definition, the excess risk is 8% for workers exposed to an average daily noise level of 85 dBA over a 40-year working lifetime.

The OSHA occupational noise standards state: "Exposure to impulsive or impact noise should not exceed 140 dB peak sound pressure." Thus, in this context, the 140 dB limit is advisory rather than mandatory [6, 8, 9]. NIOSH did not address the hazard of impulsive noise, although NIOSH stated that the provisions of the recommended standard in the criteria document were intended to apply for all [9-11]. Although there is yet no unanimity as to which criteria best describe the relationship between NIHL and exposure to impulsive noise, either by itself or in the presence of continuous-type noise, there is an international standard that has become widely used by most industrial nations. This standard (ISO 1999, Acoustics), integrates both impulsive and continuous-type noise when calculating sound exposures over any specified time period for Estimation of Noise-Induced Hearing Impairment. NIOSH concurs with this approach and recommends that noise exposure levels should be calculated by integrating all noises (both impulsive and continuous-type) over the duration of the measurement [12]. The same method was used in the present study. The scope of this study limited to Zanjan, one of the provinces of Iran.

MATERIAL AND METHODS

There are several methods to test the hearing sensitivity of an individual. It is possible, for example, to examine hearing levels with an audiometer, tuning fork, or a free field voice test. Audiometric testing is the accepted standard for measuring hearing levels, but other procedures are often used by medical personnel to identify persons with hearing impairments or hearing disorders. Testing for hearing ability may take the following forms; testing to determine if a person can hear at a specified hearing level (screening), or testing for a threshold of hearing sensitivity. Screening involves testing for the ability to detect a specified level of sound at various frequencies. An individual either responds or does not respond to the signal. Thus, they pass or fail depending upon their ability to "hear" at this one level. The pure-tone screening test usually performed and this test has become the standard method for measuring hearing.

Risk assessment was considered as the main basis for the exposure standard. For this purpose, the fence was defined as the average HTL for 1, 2, 3 and 4 kHz existing audiometric frequencies. Maximum acceptable hearing loss was considered to be 25 dB. The percentage of the occupational noise-exposed population for which the maximum acceptable occupational hearing loss will be tolerated was calculated as the quantitative risk assessment.

Normally the maximum acceptable hearing loss is separated from smaller degrees of hearing loss and normal hearing. Excess risk is the difference between the percentage that exceeds the fence in an occupational-noise-exposed population and the percentage that exceeds it in an unexposed population. In present study aging effect was considered to be 15 dB for a 65 years old person after retirement.

The study was conducted in province of Zanjan which is one out of 30 provinces of Iran. This province had the best existing field data. All workers in this
province were screened to select the appropriate cases using questionnaire. Selected workers should:
1. Have at least one audiometric record.
2. Not have an accidental hearing loss
3. Not have hearing loss due to medical surgeries, disease and etc
4. Not exposed to accidental explosions.
5. Not exposed to explosions or heavy weaponry noise during the war or army activities.
6. Not used hearing protective equipment.

Out of 4000 workers almost 1000 workers were selected after screening all of them. All of the selected workers had a base audiometric record and most of them had two consecutive audiometric records. Those with only one base audiometric record had to have another audiometric record. The new audiometric record was obtained for those with only one record. Sound pressure level at the workplaces should also be existed. Sound pressure level at those workplaces with no previous record was measured by sound level meter. Unexposed workers were considered as control group.

Before present study takes place, some other studies had been performed in all provinces of Iran. Reviewing the existing documents showed that Zanjan Province has the best record in such studies. Thus this province was selected as our studying field. This central province of Iran is almost 1/30 of the state. It is neither very industrialized nor undeveloped. The selected province could be as a good representative of the country. All industrial plants of this province are located in two cities of Zanjan and Abhar.

All workers exposed to noise in all industrial plants located in Zanjan and Abhar cities were screened for this study. Those who had been exposed to blasts, explosions, accidents or participated in war were deleted from this study. All workers who had any type of medical treatment that could influence his/her hearing loss were also deleted. Only workers exposed to noise without hearing protection equipment were used. For this purpose, all workers in both cities were screened using a questionnaire form and reviewing their files. Almost 1000 worker was selected for this purpose.

All workers in this study should have had two audiograms to estimate his/her hearing loss risk. Reviewing their files, those who did not have a preliminary audiogram were deleted from the study. For those who had one audiogram, a final audiogram was obtained by testing them.

Sound Pressure Level (SPL) in the working place was needed for each worker. It is very difficult to estimate the SPL at working place during different exposure time. Thus only one SPL either existing or measured during present study was considered as the average exposed sound level. This could be considered as a negative point for present study.

Collection of data was tedious and time consuming. A team was trained for this purpose. All workers were screened. The sound pressure level at working places was measured. A new audiogram was obtained for all workers who hadn't had a recently obtained audiogram. Collected data was analyzed.

**RESULTS**

According to Table 1, only 24 women were studied in Abhar while in Zanjan there were no women for study. Maximum age of women studied is 39 years.
Sound Pressure Levels at workplaces of all workers were also measured. Most of them were measured directly with sound level meter but some of them were calculated from measured Noise Dose Levels.

Table 2 shows the distribution of noise levels at workplaces under study. Average SPL for all workers is 89.4 dBA. Maximum SPL is 131 dBA.

Daily working hours for workers differ from each other (Table 3). Total average daily working hour is 7.4 hours with standard deviation of 0.93 hour. Minimum working hour is 3 and maximum 10 hours a day.

While data processing, almost 22 percent of the existing data as extreme and outlier data were omitted from the study. The rest of the existing data were also stratified, from sound pressure level (SPL) point of view. The minimum and maximum SPL in the workplaces are 69 and 131 dBA respectively. The majority of existing Sound Pressure Level is in the range of 80 to 100 dBA. All SPLs lower than 80 dBA were considered as one category. The workers exposed to this range of data were considered as the controlled group (who were not exposed to excessive noise in workplace). The SPLs higher than 100dBA were also considered as one category mainly because the available data, in this range is little. The rest of the existing data is divided into the following four categories:

- $80 \, \text{dB} \leq \text{SPL} < 85 \, \text{dB}$
- $85 \, \text{dB} \leq \text{SPL} < 90 \, \text{dB}$
- $90 \, \text{dB} \leq \text{SPL} < 95 \, \text{dB}$
- $95 \, \text{dB} \leq \text{SPL} < 100 \, \text{dB}$

Average hearing loss for frequencies of 1, 2, 3 and 4 KHz were calculated. Fence was determined based on NIOSH recommendations.

Fig. 1 and 2 show the hearing loss of left and right ear for total number of exposed workers including men and women. The data show that for almost 800 workers exposed to noise levels of 90 to 95 dBA, the average hearing loss for both ears is 26.3. This exceeds allowable hearing loss recommended by many institutes (e.g. 25 dBA). According to these charts, the average hearing loss for noise levels of 85 to 90 dBA for both ear is 17.9 dBA. This is in the range of recommended values for occupational hearing loss.

Fig. 3 compare the average hearing loss of each ear for men and women exposed to different occupational noise levels. These charts show that there is no any significant difference between left and right ears hearing loss at different exposed noise level.

![Fig 1. Average hearing loss of left ear, for men and women in Zanjan and Abhar factories](image1)

![Fig 2. Average hearing loss of right ear, for men and women in Zanjan and Abhar factories](image2)

![Fig 3. The comparison of hearing loss for both ears of men and women in Zanjan and Abhar factories](image3)
The comparison of hearing loss in controlled and exposed groups of men and women to exceeding occupational noise levels show that there is a significant difference in their hearing loss.

**DISCUSSION**

Hearing sensitivity at 0 dB(HL) is normalized to represent average normal hearing for young, otologically normal adults (male and female) between the ages of 20 to 29 [14]. The range of normal hearing is considered to be between 0 to 25 dB (HL). The four frequencies pure tone average of hearing levels at 500; 1,000; 2,000; and 3,000 Hz were used for mid-frequency hearing loss. High frequency range of 3,000; 4,000; 6,000; and 8,000 Hz was used for hearing impairment. Threshold of 25 dB (HL) and above was considered abnormal but the calculation of hearing was also carried out using 0 dB (HL) as reference [15]. An arithmetic average of 25 dB loss defines the boundary between just adequate and inadequate hearing sensitivity for the purpose of speech recognition. For practical purposes a hearing loss of 25 dB will allow speech to be just understood satisfactorily, while loss of 92 dB is regarded as total hearing loss. If a person suffers a hearing loss between 25 dB and 92 dB the person hearing is said to be impaired, where the degree of impairment is determined as a percentage at the rate of 1.5 percentage points for each dB loss above 25 dB [16].

Results obtained from the present study show that the occupational noise levels of 90 to 95 dBA can lead to hearing losses greater than 25 dBA. Results also show that occupational noise levels of 85 to 90 dBA dose not lead to hearing losses greater than 20 dBA. This result well agrees with those obtained by others such as NIOSH 1972, Lempert and Henderson 1973.

The comparison of hearing loss for non exposed workers and exposed workers to noise show that the noise levels of less than 80 dBA will not lead to any significant hearing loss. According to the results of present study, 85 dBA can be recommended for a national occupational noise limit in Iran. The present study also shows that the women are more susceptible to noise than men.

The application of existing field data to recommend a national occupational noise standard has the following restrictions:

1. A lot of existing data should be screened to reach satisfied data.
2. There are uncertainties in existing data including:
   - The uncertainty on noise levels measured in the past.
   - The audiometric tests performed in the past.
   - The uncertainty on application of hearing protective equipment for some periods in the past.
   - The application of hearing conservation program in some factories in the past.
   - The combination of men and women in the studied industries.
   - Variation of noise levels for workers in the past.

Considering the above restrictions and the results from the present preliminary study it is strongly recommended that for final recommendation of a national occupational noise standard a comprehensive study is required to consider whole country.

**CONCLUSION**

The results of this study shows that occupational noise levels of 90 to 95 dBA can lead to hearing losses greater than 25 dBA, so periodic check up of workers’ audiogram is extremely necessary to determine auditory threshold levels of the persons working in noisy area. According to this study a comprehensive study that consider and follow up different categories of working areas, need to be designed to be able to recommend national occupational noise standard in Iran.

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