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Original

# Evaluation of Occupational Exposure to Noise and Its Effect on Hearing Loss of Workers in a Cement Factory in Northern Iran

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## ABSTRACT

**Background and:** Industrial noise affects the health of workers and can disrupt the daily communication of workers. The aim of this study is to evaluate occupational exposure and investigate the hearing loss of workers in the two sections of cement mill and material mill of a cement factory in north of Iran. **Methods**: This was a descriptive study conducted on 52 persons in 2020. At first, the sound measurement was performed with the Casella CEL 450 device in A-weighting network at workers' workplaces based on area-based method. Then, by referring to the medical records and demographic information, the amount of hearing loss in the frequencies of 250-8000 Hz was evaluated. Finally, the results were analyzed using SPSS software version 19. **Results**: Independent samples T-test showed that the average sound pressure level in the cement mill section (85.50 dBA) is higher than the material mill section (74.38 dBA) (P-value = 0.01). The highest rate of hearing loss was observed at frequencies of 4000 and 8000 Hz. The hearing loss rate was 10 decibels for both ears in the material mill section. No significant difference was observed in the amount of hearing loss in the right and left ears of employees. **Conclusion**: Noise pollution and hearing loss is common among employees of cement industry. To prevent hearing loss, it is necessary to evaluate and monitor the noise pressure level. Furthermore, engineering measures in the field, using personal protective equipment, as well as adequate training of employees should be conducted.

**Keywords**: Hearing Loss; Noise-Induced; Analysis; Frequency Analysis.

## Introduction

Noise is one of the first known pollutants in the cement industry, which is caused by various equipments installed in the cement production plant. [1] Of course, vibrations should also be added to it. The progress of human societies toward industrialization and the growing need for industrial products and materials has led to a significant increase in workplace noise. Hearing diseases, especially hearing loss due to workplace noise, are a common problem in many industries. Ramazini considered hearing loss to be an occupational hazard. Noise can interfere with work, rest, sleep and communication. [2] The US Safety and Health Administration estimated that 7.9 million

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manufacturing workers are exposed to noise above 80 decibels. [3] A 2004 study by Sulkowski et al. revealed that more than 35 million workers in Europe were exposed to more than 85 decibels. In Poland, with a population of 5 million; an estimated 650 people who were exposed to excessive noise were at risk for hearing loss. [4] Noise, in addition to adversely affecting the auditory system as a general stressor, may lead to high blood pressure, cardiovascular problems, nerve irritation, anxiety, and psychological problems. [5] Noise control is one of the first measures to control pollutants in industry. [6,7] There is ample evidence that workers who are exposed to excessive noise at the workplace are at a higher risk of accident. [8] According to the National Institute of Occupational Health and Safety (NIOSH), hearing loss is one of the 10 most common work-related illnesses. [9] Moreover, Daniell et al. in their study in the United States in 2006, demonstrated that out of 1557 workers studied, 50% of them were exposed to noise over 85 decibels and their hearing loss had a statistically significant relationship with the rate of occupational noise. [10] The study by Ghotbi et al. on hearing loss of workers of an industrial unit suggested that the hearing loss in the left ear was 16.31, the average hearing loss in the right ear was 15.38, and the overall hearing loss was 14.72. Results of the Atmaka's study in Turkey in 2005, which assessed the health of workers exposed to noise in the textile industry, showed that 61% of employees had neurological problems and 31% have hearing impairments. [11] In Singapore, the most common work-related illness is hearing loss due to exposure to sound. Among workers exposed to noise in Korea, Hong Kong, Singapore, and the Philippines, 12%, 15%, 40%, and 74% of workers suffered from hearing loss of more than 30 decibels, respectively. [12] Normal hearing is defined as the ability to detect sound in the auditory frequency range in accordance with existing standards. However, individual hearing ability is diverse and this difference is influenced by environmental and physiological conditions. For example, with age, hearing sensitivity decreases or in noisy environments, this decrease is doubled. [5] Therefore, it is necessary to adopt a comprehensive hearing program at workplace. On the other hand, protecting the health and safety of workforce from the dangers associated with work activities is essential and the foundation of the health and dynamic economy of any country. Therefore, this study was conducted to evaluate noise exposure and its consequences in workers of materials mill and cement mill in a cement factory in Northern Iran to determine the frequency and severity of hearing loss due to noise.

## Methods

This descriptive-analytical study was performed in 2020 in a cement factory in Northern Iran. In this factory, two halls are full of noise, so measurements were made in these units and the personnel of the units were included in the study by census. Picture 1 shows the steps of the procedure. Peripheral sound monitoring in the mentioned units was performed by environmental method (stationing) with Casella CEL 450 device in A-weighting network. Frequency analysis was performed at working stations. According to the purpose of the measurement, assessing workers' exposure to noise, A-weighting network was used because this network is proportional to the sensitivity of the human ear. [5]



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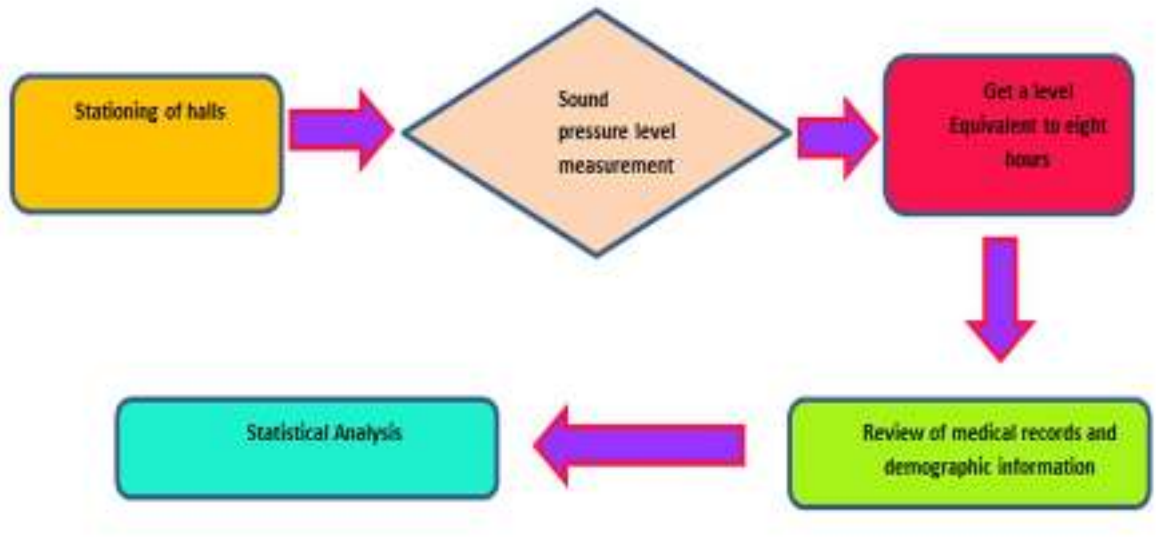


Picture 1. The research performing steps

To determine the environmental measurement plan, after preparing the initial plan of each section, drawing the architectural plan and determining the location of sound generating sources, according to the area of the sections, networks (stations) in each unit were divided into separate dimensions.

The response speed of the device was set to slow mode, which is suitable for uniform sound. Environmental measurements and assessments were performed by regular network method. In this way, in the material mill unit with 30 employees with dimensions of 12 * 12 square meters to 4 * 4 square meters station, the number of stations was 6. In the cement mill unit with 22 employees with dimensions of 48 * 66 square meters, the number of stations was 39 with dimensions of 6 * 6 square meters. In both units, the combined sound of the working environment was performed by Casella CEL 450 device in the A weighing network and the speed of the device was on the slow mode. It should be noted that the ambient sound in the hall is uniform and the personnel are exposed to noise from the morning when the devices are turned on. Therefore, it was enough to measure the sound pressure level and no dosimetry was done for the personnel. Since the sound pressure level of the source is uniform over time but the pressure level around it is different and the workers are moving around it, at several points around the device at equal distances from the source, the sound pressure level was measured, then, the values were converted to a number using the formula of average sound pressure level ($\overline{\mathbf{LP}}$).Therefore, the average sound pressure level for each of the materials and cement mills was calculated according to the following formula:

(1)

$$\overline{\mathbf{LP}}\ (\text{dB}) = 10\ \text{Log}\ [\frac{1}{n} \sum_{i=1}^{n} 10^{\frac{lpi}{10}}]$$

In the above relation, $\overline{LP}$ is the average sound pressure level of the source, n is the number of measuring points, and lpi is the sound pressure level at each point.

(2)

$$L_{eq}(dB) = 10\log\left[\frac{1}{T}\sum_{i=1}^{n} t_i 10^{LP_i/10}\right]$$

In this relation, Leq is the exposure equivalent level, T is the reference time, which here is equal to eight, and ti is the duration of the i-th exposure time in hours. [13] In order to monitor the files and assess the hearing condition, the latest hearing results


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recorded in the workers' job record, which was done in 2020, were used. The frequencies used in this audiometry were 8000, 6000, 4000, 3000, 2000, 1000, 250,500, and the results were recorded in audiogram sheets.

Demographic information was extracted by referring to the periodic examination files of personnel including age and work experience. Then, the rate of hearing loss by workplace, minimum and maximum hearing threshold in the right and left ears at different frequencies were analyzed. The following formulas were used to obtain the extent of hearing loss:

(3)

$$\boldsymbol{NIHL} = \frac{(\boldsymbol{TL_{500Hz}}) + (\boldsymbol{TL_{1000Hz}}) + (\boldsymbol{TL_{2000Hz}}) + (\boldsymbol{TL_{4000Hz}})}{\boldsymbol{4}}$$

In this formula, TL is the hearing threshold at the desired frequency in each ear in terms of dB, NIHL is the permanent hearing loss caused by sound (dB).

The total permanent loss of both ears was calculated from Equation 4:

(4)

$$NIHL_t = \frac{(NIHL_b \times 5) + (NIHL_p)}{6}$$

In this relation, the NIHLt is the same as the total permanent loss of both ears (dB), the NIHLb is the permanent loss of the stronger ear (dB), and the NIHLp is the permanent loss of the weak ear (dB).

And percentage of disability of each ear (MI) was obtained with equation 5 below:

(5)

MI(%)=(NIHL-25) × 1.5

In order to obtain the percentage of total hearing disability (MIt), equation 6 was used:

(6)

$$MI_t = \frac{(MI_b \times 5) + (MI_p)}{6}$$

In equation 6, MIb is the percentage of disability in the stronger ear and MIp is the percentage of disability in the weaker ear (13). It should be noted that the authors corrected the results of audiometry using the recommended standard tables regarding the effect of worker age. It is an intervening variable which affects the rate of hearing loss of workers. Finally, data were analyzed using statistical analysis. At First, the normality of the data was checked by Kolmogorov-Smirnov test, and then, statistical analysis was performed by Pearson correlation coefficient test, independent t-test and Spearman test. Statistical analyzes were carried out using SPSS software version 24. Significance level in this study was considered to be 0.05.

## Findings

According to the results of the study, the average age of workers in the material mill and cement mill units were 32.67 ± 4.21 and 32.50 ± 2.70, respectively, and the average work experience of workers in terms of years in the material mill unit was 5.83 ± 1.44 and in the cement mill unit was 5.14 ± 0.56. Information about the age and work experience of the employees of the two units is presented in Table 2.

Furthermore, the results of average sound pressure level and the equivalent level of eight hours of noise in the stations of the material mill and cement mill are shown in Table 3. Only the average sound pressure level of the cement mill unit was higher than the standard value of 85 dB. Besides, the noise measured in the dining hall, where the staff was present for about half an hour, was equal to 68 dB of network A.

The average hearing loss of the right ear in the material and cement mill unit at 4000 Hz frequency was 25.50 ± 3.79 and 26.82 ± 3.95, respectively, at the frequency of 8000 Hz in the material mill unit, it was 26 ± 3.81, and in the cement mill unit, 29.55 ± 8.72 was obtained .For the left ear at a frequency of 4000 Hz for the material milling unit, 25.50 ± 3.79, for the cement milling unit, 25.91 ± 2.51 ,and at a





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frequency of 8000 Hz for the milling unit of materials and cement respectively 26 ± 3.81 and 28.64 ± 8.62 were obtained.

The maximum hearing loss of the right ear was 55 dB in the material milling unit at a frequency of 6000 Hz and in the cement milling unit, it was 50 dB at the frequency of 8000 Hz. Moreover, the maximum hearing loss of the left ear in the unit of material mill and cement mill was equal to 55 dB, which was observed at frequencies of 6000 and 8000 Hz, respectively. The amount of hearing loss in both ears in the cement mill unit was more than the material mill unit, and also it was more in the right ear than the left ear. In the frequency of 4000 to 8000 Hz, more loss was observed than other frequencies.

According to Figure 1, maximum hearing threshold of the right ear in the cement mill unit at 29000 Hz was 29.55 and the minimum at 250 Hz was 20.23. For the left ear at 8000 Hz, it was 28.64, and at 250 Hz, it was 20 dB. For the material milling section for both frequencies 250 and 8000 Hz, the maximum hearing threshold was 26 and the minimum was 20 dB. Pearson correlation coefficient between left and right ear's hearing loss was significant at the level of $p<0.05$. Therefore, the correlation coefficient was $r = 0.743$ and P-value <0.001.

The results of the audiometric test indicated that in some hearing frequencies, especially in frequencies above 4000 Hz, a decrease in hearing power or an increase in the hearing threshold has been observed. According to Figure 2, the amount of hearing loss in these two units at frequencies above 3000 Hz is as follows:

In the cement mill unit, 27.3 dB was for the right ear and 22.7 dB was for the left ear; in the material mill unit hearing loss occurred at 10 dB in the left ear and the same happened to the right ear.

According to the T-test, there was no significant difference between the right ear of material mill and cement workers among people with hearing problems (P-value = 0.272). As can be seen in Table (1), there is no difference in the left ear among employees with hearing problems in the mill and cement unit (P-value = 0.549).

Table 1. Comparison of hearing threshold in workers with hearing problems

| | place | N | Mean | Std. deviation | Std. error mean | Sig. (2-tailed) |
|---|---|---|---|---|---|---|
| Right ear | Material mill | 30 | 23.8750 | .94857 | .17318 | [a].272 |
| | Cement mill | 22 | 24.2045 | 1.19183 | .25410 | |
| Left ear | Material mill | 30 | 23.8333 | .98114 | .17913 | [a].549 |
| | Cement mill | 22 | 23.9773 | .62635 | .13354 | |

a: T-test, P-values less than 0.05 were considered to be significant

Table 2. Average age and work experience (year) among workers

| Title | Mean ± SD | Mean ± SD | | Minimum | | Maximum | |
|---|---|---|---|---|---|---|---|
| Variable | Total people | Material mill N=22 | Cement mill N=30 | Material mill | Cement mill | Material mill | Cement mill |
| Age (years) | 32.59 ± 3.62 | 32.67 ± 4.21 | 32.50 ± 2.70 | 25 | 28 | 43 | 37 |
| Work experience (years) | 1.19 ± 5.54 | 5.38 ± 1.44 | 5.14 ± 0.56 | 4 | 4 | 10 | 7 |

Table 3. Average sound pressure level in Material mill and Cement mill sections

| Department | Data standard deviation | Average sound pressure level (dB) | Leq (dB) | p-value |
|---|---|---|---|---|
| Material mill | 0.74 | 74.38 | 74.11 | [a]0.01 |
| Cement mill | 1.17 | 85.50 | 85.22 | |

Independent sample T-test





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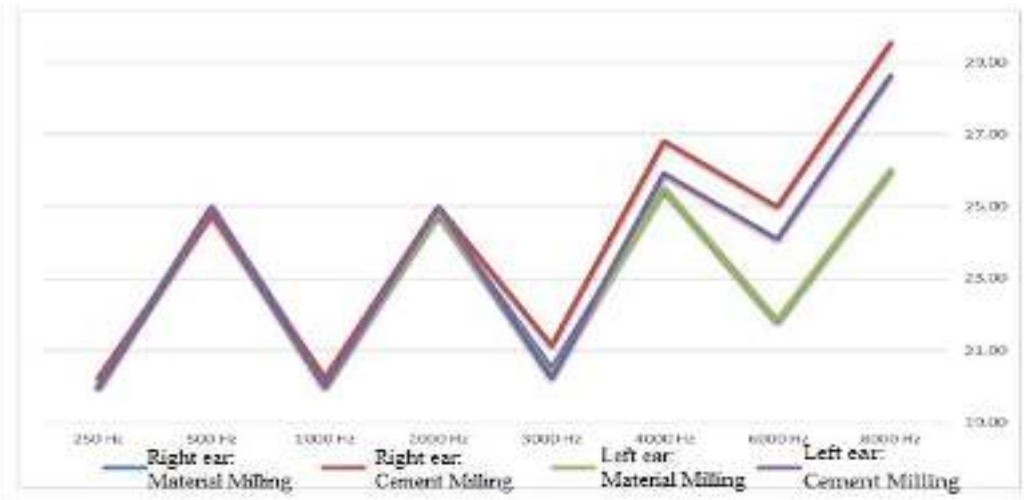


Figure 1. Comparison of hearing thresholds for different frequencies

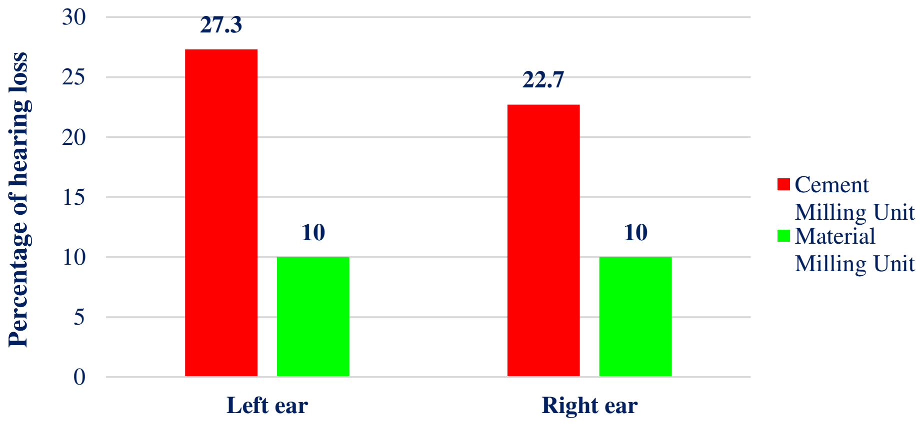


Figure 2. Percentage of hearing loss at frequencies above 3000 Hz

## Discussion

According to the results of this study, most of the hearing loss happens at frequencies of 6000 and 8000 Hz. In addition, according to the environmental monitoring performed in different workplaces, authors realized that the average sound pressure level in the cement mill section is higher than the allowable limit. According to the results of the recorded examinations, this increase in sound pressure level has caused some hearing and non-hearing problems among the workers. At the same time, in the material milling section, the sound pressure level has not reached 85 decibels, and in this unit, the personnel are not exposed to noise above the allowable limit. A total of 52 people were studied, of whom 9 employees are afflicted with hearing loss, 3 in the material mill and 6 in the cement mill. In general, 17.3% of the employees suffer from hearing loss.

The reason why three people in the material mill section suffer from hearing loss while the sound pressure level is about 74 dB is because these people have already been exposed to noise above the permissible level in another unit. They were among those who had more work experience than other colleagues. The results of the audiometric test show that at some frequencies, especially at frequencies above 4000 Hz, a decrease in hearing power or an increase in the hearing threshold was observed. According to the measurements and examinations, the increase in sound pressure level in the cement mill unit has caused hearing problems. A comprehensive program should be widely prescribed and implemented to control the sound level in this unit.

According to the T-test, there is no significant difference between the right ear of personnel in the material mill and cement mill among people with hearing problems (P-value = 0.272). Regarding the left ear, there is no significant difference between employees with hearing problems in the material mill and cement mill as well (P-value = 0.549). This indicates that in the cement plant environment, sound has affected both left and right ears at the same time, and an increase in the hearing threshold for both ears has occurred in the same proportion. An increase in the hearing threshold was observed for workers in environments above the sound level threshold, and the greatest hearing loss was at frequencies of 6000 and 8000 Hz.

The rate of hearing loss among the employees of the cement mill was somewhat higher than the employees of the materials mill. According to environmental measurements, authors observed that the average sound pressure level in the cement mill section is 0.5 dB more than the allowable limit (85 dB).

The degree of hearing loss is determined by hearing examinations, in which a person's ability to hear a pure tone at specific frequencies is measured. Audiometry is an objective test and people's response to it is different during diverse tests at different times. [14] Studies indicate that increasing the hearing threshold at high frequencies is common in industrial environments. The experiments conducted in this study confirm the increase in the hearing threshold at high frequencies. [15]

Studies by Hernandez-Gaytan et al., assessed the sound level of a cement plant and examined the hearing loss of cement workers. It demonstrated that 55% of the studied workers suffered from hearing loss due to exposure to high sound levels, which works as the available evidence for findings of this study. [16] Studies by Bary et al., on workers at the Urmia White Cement Factory illustrated that 6.5 percent of workers were suffering from hearing impairments, and this problem was particularly prevalent at frequencies of 4,000 Hz and above, which is similar to the results of our research. [17]

The results of a study by Sexivas et al. in the United States in 2005, shows that the highest hearing loss among 328 workers exposed to harmful noise is in the region of 4000 Hz. The average annual loss in that frequency is 0.5 dB, which is in accordance with the results of this research. [18] The findings of Latkowsi et al., in the refining and petrochemical industries showed that there is mild hearing loss at high frequencies among exposed workers, which is in line with the findings of the current study. [19] In the study by Zare et al., entitled "the Effect of Noise Pollution and Hearing Loss in One of Iranian Oil Industries", they found that in the studied units, the level of sound pressure is higher than the allowable level. The results of the study regarding the hearing threshold of employees exposed to noise showed that these people were afflicted hearing loss at high frequencies. [20] The study by Mansouri et al., in 2001 regarding the automotive industry, worked on hearing loss among workers exposed to noise pollution with high sound pressure level. Its results were similar to the findings of this study. [21] A study on soft drink workers in Sari found that left ear was more sensitive to sound than the right ear. In addition, severe hearing loss was observed at 4000 Hz, which was the link between loud sound exposure and hearing loss. It is similar to this research; however, in this study the hearing loss in the right ear was more than the left ear. [22]

In Hong and Kim's study, a significant relationship was found between occupational



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exposure to noise and hearing loss, which is consistent with the results of this study. [23] Chen and Tsi's studies in one of Taiwan's oil industries showed that there was noise exposure and the possibility of noise-induced hearing loss in the industry. It is essential to determine noise exposure of employees working in these industries and control noise and reduce employees' exposure. [24] The findings of similar domestic and foreign studies represent diverse results. This is due to different levels of noise pollution in different industrial processes, different economic conditions in terms of noise control, using personal protective equipment as well as individual genetic characteristics and simultaneous exposure to certain contaminants and drugs. [25-27]

## Conclusion

According to the findings of the study, researchers concluded that cement industry is one of the industries with noise pollution. Exposure to loud noise can cause hearing loss in employees. According to the results of this study, in order to reduce the process of hearing loss, it is necessary to evaluate and monitor sound pressure level, engineering measures in the field of noise control in noisy environments, use of personal protective equipment such as ear muffs and ear plugs. Moreover, there should be adequate training of employees regarding the effects of noise and how to use personal protective equipment. Periodic audiometric monitoring is absolutely necessary to detect early-stage hearing loss as part of a hearing protection program.

## Conflict of Interest

Authors declared no conflict of interest.

## Acknowledgment

This study with the code of ethics IR.NKUMS.REC.1400.100 has been approved by the ethics committee of North Khorasan University of Medical Sciences. The authors also thank the esteemed management and staff of the Cement Company and the colleagues of the Health Center and all those who have helped us in this project.

## Authors contribution

Research design: M. E. K

Data collection: M. V

Data analysis: H. M

Writing and editing the article: F. S

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