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INDUCED NOISE DUE TO ACTIVITIES AT CONSTRUCTION SITE AND ITS IMPACT ON CONSTRUCTION WORKERS HEALTH

Md. Omar Faruk Rahat[a]*, Md. Arifur Rahman Chowdhury Mahfuj[a], Md. Jahir Alam[b], Noyon Loskor[a], Sibbir Ahmed[b]

[a]Department of Civil Engineering, Sylhet Engineering College, School of Applied Science and Technology, Shahjalal University of Science and Technology, 3100 Alurtol Road, Sylhet, Bangladesh
[b]Department of Civil and Environmental Engineering, Shahjalal University of Science and Technology, 3114 University Ave, Sylhet, Bangladesh

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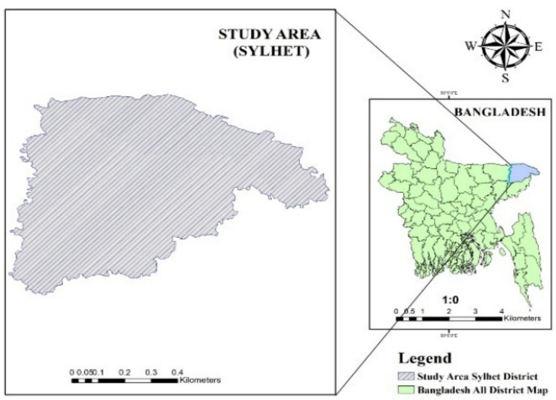
*Corresponding author
mahfuj.ce@sec.ac.bd



Abstract

The construction process would generate a great deal of noise pollution, which is extremely harmful to the workers' health. This research developed a comprehensive evaluation framework for measuring the negative impact on health caused by induced noise due to construction activities. The study was conducted by selecting a group of workers from various sections of a construction site, including concrete mixing operation, reinforcement cutting, brick crushing operation, and formwork, and assessing their hearing capabilities at two intervals over a six-month period. At first, the hearing loss of workers was initially assessed through a Pure Tone Audiometry (PTA) test to evaluate their hearing ability. Subsequently, the Disability-Adjusted Life Years (DALY) for the workers were calculated to quantify the impact of hearing loss on their overall health. The framework includes the establishment of standardized criteria for assessing noise exposure, the definition of health risks associated with construction work, and the quantification of the resulting health damage. Also, it outlined the improvement of workers' occupational health levels. Through field survey using a Digital Sound Level Meter (Model: SL-4001), it was found that noise generated by heavy machinery exceeds the limit of the standard noise level. Throughout the 4-year construction of the ILST project, the cumulative Disability-Adjusted Life Years (DALY) for all workers is 1.875a, due to the Concrete mixing operation the highest amount of harm (DALY = 1.145a) occurred. An audiometrist performed a PTA test at an interval of 205 days and found a slight change in the capacity of hearing level. This study emphasized awareness of the harm caused to the workers involved by the noise pollution generated for the construction work.

Keywords: Hearing loss, Sound level, PTA test, DALY, Construction Noise, Safety measures, and Construction machinery.

1.0 INTRODUCTION

A pressure variation wave that travels through air and is detected by the human ear is known as sound. Noise pollution is the term used to describe excessive or unwanted sound that has the potential to cause annoyance or hearing loss.

Construction noise refers to the sounds generated by activities and equipment on construction sites, including machinery operation, material handling, and worker interactions at the site (Mir et al., 2023). Different classification levels for construction site noise are utilized. The Noise Policy Statement for England (NPSE) classifies noise pollution into three distinct categories: environmental noise, neighbor noise, and neighborhood noise (Waddington et al, 2011). Construction site noise is included in the category of neighborhood noise, including noise generated by industrial operations, construction areas, and street traffic. Noise pollution on construction sites develops from various sources, such as the operation of loud equipment and vehicles, the use of raised voices, and physical activities like striking, the process of drilling, loading and unloading of materials, and excavating. However, the noise generated by these construction processes often goes unnoticed as a potential public health concern. As urbanization continues to accelerate, the incidence of construction projects in and around urban areas has grown in parallel, leading to increase the intensity of noise pollution. The detrimental effects of excessive noise on public health and well-being have been a subject of growing concern, prompting an urgent need for comprehensive research and action. In construction sites, multiple works are held at the same time. Thus, a noise pollution environment is created in the construction sites. Specific legislations on noise pollution are implemented by first-world countries such as the USA, UK, New Zealand, Australia, Denmark, Japan, Germany, etc. In Bangladesh, an environmental law was developed on September 7, 2006, named Bangladesh Environmental Protection Authority (BEPA) (register no D A-1). The mandate to establish policies, strategies, and standards that specify maximum tolerable levels of noise is held by the BEPA. According to BEPA, The maximum permissible sound levels have been specified at 75 dB for construction and industrial zones, 65 dB for commercial zones, 60 dB for zones both residential and commercial or industrial, and 55 dB for residential zones. On the other hand, "It is recommended by the World Health Organization (WHO) that noise levels should not exceed 70 dB over 24 hours, and 85 dB over a 1-hour period to avoid hearing impairment" (Schwela, 2000). Additionally, the WHO recommends that children are not exposed to noise levels above 120 dB (Schwela, 2000). WHO's guidelines also added that the acceptable noise level thresholds are 55 dB for outdoor residential regions and 70 dB for commercial sectors and regions where there is traffic. The lower noise exposure level is 80 dB and the higher noise exposure level is 85 dB defined by the European Directive 2003/10/EC (Canetto et al, 2009). This directive requires hearing protection to be used when the noise level reaches 85 dB and limits exposure to 87 dB while considering the effectiveness of hearing protectors. In this study, standard sound level data from the ASHA (American Speech-Language-Hearing Association), as outlined in Clark, J. G. (1981) "*Uses and Abuses of Hearing Loss Classification* (Asha, 23, 493–500)", was used to measure the hearing loss data, as presented in Table 1.

Noise is recognized as an enormous occupational health risk, which is very common in the construction area. Construction induced noise poses a significant problem as it causes stress among people in the community and can result in harm. Construction workers' rate of intensity of noise exposure is strongly affected by the machinery and functions implemented in the construction work (Hong, 2005), which mostly overtake their usual limits of 80 dB. A large number of these noises create a risk to workers in the construction industry since hearing protection equipment is not being used properly (NIOSH, 1988). It is stated by the WHO that noise has a direct effect on health. Exposure to high levels of noise increases the impact of noise on human health by inducing deafness, hearing loss, and headaches. Noise-Induced Hearing Loss (NIHL), occurred by chronic exposure to daily noise levels of 85 dB. Generally, noticing the 3, 4, or 4 kHz is the first sign of NIHL (May, 2000). Because of the excessive amount of noise levels in construction, noise-induced hearing loss is one of the most significant and common occupational health problems in this sector (Hessel, 2000; Hong, 2005). Quality of workers' life (May 2000) and communication and safety may be hampered (Suter 2002) by such exposure. According to an extensive investigation of self-reported hearing damage in industrial field, the construction fields employed the greatest proportion of workers with NIHL (Tak and Calvert, 2008).

"Excessive noise exposure beyond the recommended duration may result in hearing loss, stress, high blood pressure, sleep disruption, decreased productivity due to distraction, and a general decline in quality of life" (May, 2000). Besides, the material used in construction work such as cement, aggregate, reinforcement, etc. harms workers' health a lot. Such harms include skin diseases, hearing impairment, psychological collapse, hypertension, vertigo, and sleeplessness. (Park et al, 2020). The aim of the study is to find out workers and neighbors' impact due to construction noise pollution. The construction noise impact survey was conducted using questionnaire survey method and hearing loss test for the workers involved in different types of construction over 5 years.

1.1 Noise and Occupational Hearing Loss

Occupational loss of hearing resulting from exposure to excessive sound poses a significant risk to construction workers due to the consistently high levels of noise present on job sites. Machinery, power tools, and equipment generate loud sounds, subjecting workers to prolonged exposure that can damage their hearing over time. Without proper protection, the inner ears are vulnerable to harm, leading to gradual hearing loss that may go unnoticed until it significantly impacts daily life.

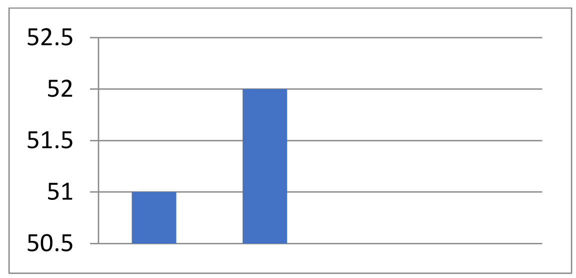


Figure 1 Construction Statistics

A construction statistic in USA "National Health Interview Survey" data from 2014 (Kerns et al, 2018) were examined and is presented in figure 1.

- Approximately 51% of workers in the Construction industry have encountered hazardous levels of noise (Kerns et al, 2018).
- Approximately 52% of construction laborers exposed to noise are reported not using hearing protection devices (Green et al, 2021).

1.2 Hearing Loss and Tinnitus

The perception of a sound that is generated by the body itself can be defined as tinnitus (Grossan and Peterson, 2017). The sound can be heard within or beyond the head, or mostly in each or both of the ears, the sensation is most typically defined as ringing in the ears (Bauer, 2018).

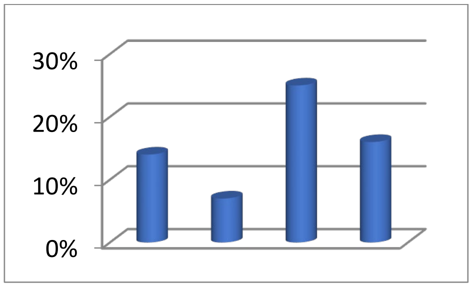


Figure 2 Hearing Loss and Tinnitus

As shown in the figure 2, The USA "National Health Interview Survey" data from 2014 (Kerns et al., 2018) indicates that nearly 14% of construction workers experience hearing loss. "Over 7% of US construction workers have tinnitus" (Masterson et al, 2016). In almost 25% of tests, noise exposure there is a significant hearing impairment among construction workers (Deddens et al, 2015). Hearing damage is a type of hearing loss that impacts daily activities. A case study of hearing damage in US noise-exposed workers found that hearing damage in both ears is experienced by 16% of construction workers. (Masterson et al, 2018).

1.3 Degree of Hearing Loss

According to ASLHA the degree of hearing impairments (ASLHA, 2015) indicates the intensity of the loss. The following table represents one of the more often-used classification systems. The numbers in the decibels (dB) indicate the values of the patient's hearing loss. This table was used as the standard measure of hearing loss for comparison with the PTA test results conducted on the workers.

Table 1 Degree of hearing loss and its range in decibel (dB) unit

Degree of hearing loss	Hearing loss range (dB HL)
Normal	-10 to 15
Slight hearing loss	16 to25
Mild hearing loss	26 to 40
Moderate hearing loss	41 to 55
Moderately severe hearing loss	56 to 70
Severe hearing loss	71 to 90
Profound	91+

Source: Clark, J. G. (1981). Uses and abuses of hearing loss classification. Asha, 23, 493–500

1.4 Study Area

This study has been carried out at three targeted construction site of building project of the Institute of Livestock Science and Technology (ILST), Sylhet, Bangladesh. This project is situated at 24°54'30.3"N 91°54'14.1"E, in Sylhet City within Sylhet division which is the northeastern region of Bangladesh. Sylhet is one of the rapidly growing metropolitan areas, situated at 24.85° latitude and 91.80° longitudes. The site is situated on the northern bank of the Surma River, near the easternmost point of Bengal. The following is the map of Sylhet District.

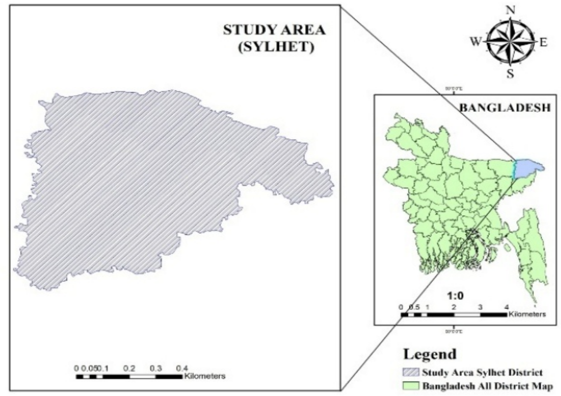


Figure 3 Study Area Sylhet District

The Institute of Livestock Science and Technology was proposed by the Livestock Directorate under the Ministry of Fisheries and Livestock. The study area ILST was selected for conducting this research, as the huge construction project was in its early stage and especially, there was a good chance of finding the same workers after six months for follow-up tests, ensuring reliable results.

2.0 METHODOLOGY

Extensive use of modern machinery is a major noise generator at construction sites. Heavy machinery and power tools can generate noise in the range of 80 dBA to 120 dBA, construction activities have a noise limit of 90 dBA (Wani, 2021), and exposure duration significantly affects the respiratory rate and heart rate (Mir et al, 2023). Laborers yelling during plastering and roof work can also generate sound due to the different heights of trusses. Heavy equipment can raise noise and vibration during construction. Massey and Bande reported that people residing over 200 m away from construction sites where modern machinery is used experience slight headaches and discomfort in their ears (Massey and Bande, 2024).

Data from the Institute of Livestock Science and Technology (ILST), in Sylhet, Bangladesh, served as the foundation for this prevalence analysis. To ensure compliance with ethical standards and facilitate access to the workers and the site for data collection, permission was obtained from the project manager. Three steps have driven this investigation. First, calibration of the sound level meter (Model: SL-4001) was performed. Second, the noise levels of various construction activities were measured. To determine the different noise percentiles, a sound level meter was used. The last step was the PTA test, which consisted of a physical examination along with standardized audiometric testing. After all of the steps were taken place, the analysis and processing of data was performed in a manner way. These results were collected from a medical examination known as the Pure Tone Audiometry (PTA) test. The data of this test were taken twice to evaluate the long-term impacts of noise caused by construction with a total interval of 205 days between January 27, 2023, and August 20, 2023.

An overview of the study is presented in the following flowchart shown in figure 3

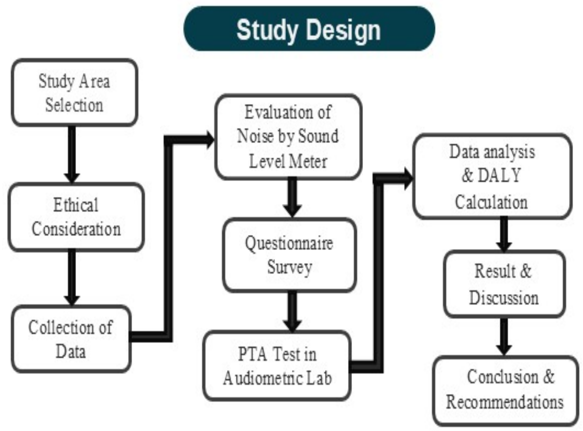


Figure 4 Study Design

2.1 Data Collection Methods and Tools

Noise measurements of construction machinery were performed by using a sound level meter (Model: SL- 4001) with a measurement range of 35 to 130 dB at the ILST construction site. Almost 50 construction workers were selected for the questionnaire survey based on their prolonged work experience in high-exposure areas of the construction site. General information about their work experience and health issues was gathered, and candidates for the Pure Tone Audiometry (PTA) test were identified through the survey.

2.2 Measurement of Noise Level at Different Sites

The noise intensity data induced from various construction activities was collected from the ongoing ILST construction project. Based on the different working statuses, the project site was divided into three sub-categories: A, E, and F. The sound intensity was measured at a interval of 1m, 3m, and 5m from the source of the noise such as rebar cutting machine, concrete mixing machine, excavator, dump truck, brick crusher, etc. using the SLM. Approximately 10 minutes was spent to collect each sound measurement data for maintaining the highest accuracy. After that, the average of the collected data was used for further calculation.

2.3 Assessment of Noise-induced Hearing Loss

The selected four workers from the questionnaire survey went through the PTA (Pure Tune Audiometric) test. The Pure Tune Audiometric is a test that determines hearing sensitivity. Using a microprocessor the PTA test was conducted for both ears, measuring 0.25 kHz 0.5 kHz, 1 kHz, 2 kHz, 4 kHz, and 8 kHz. The audiometer was calibrated according to American National Standards Institute. A SAAST (self-administered audiometric screening test) was performed in a double-walled audiometric booth, which met the ANSI criteria for audiometric rooms, by a certified audiometrist in Sylhet City.

2.4 Assessment of Health Risk

In this study, the "Health Damage Assessment Model" is used to determine the occupational noise exposure level of the workers of the ILST (Institute of Livestock Science and Technology) construction project. The model primarily consists of three key components: the establishment of standardized criteria for assessing noise exposure, the definition of health risks associated with construction work, and the quantification of the resulting health damage.

2.4.1 Standardization of Noise Exposure

The noise exposure level will be estimated according to the Technical Guidelines for Noise Impact Assessment developed by the Ministry of Ecology and Environment People's Republic of China, 2009 (Ministry of Ecology and Environment PRC, 2009), as well as the estimation is performed by the following equation Eq. 2.4.1 (Chen et al, 2020).

$$L_{A,eq} = 10Log\left\{\frac{1}{T}\sum_{n=1}^{N} t_n\, 10^{0.1L_{A,n}}\right\} \ldots\ldots\ldots\ldots (2.4.1)$$

Where $L_{A,eq}$ is the A-weighted equivalent continuous sound pressure level (dB(A)). T represents the total measuring time, (h), and t_n is the measuring time of point n, (h) $L_{A,n}$ represents the noise pressure level of measuring point n.

As per the occupational health risk assessment system, the exposure level of construction workers in a potentially dangerous work environment should be determined using the 8-hour daily average exposure quantity. The following equation 2.4.2 (Chen et al, 2020) can be used to find the equivalent daily average exposure noise based on appropriate specifications (ISO, 2009).

$$L_{EX,8h} = L_{A,eq} + 10Log\left(\frac{T_e}{T_0}\right) \ldots\ldots\ldots\ldots (2.4.2)$$

Where $L_{EX,8h}$ is the 8-hour daily average noise exposure, (dB(A)). T_e represents the daily effective working hours, and T_0 is the reference value of working hours, which is 8 h.

Table 2 presents the effective working hours for different operations conducted in the study area.

Table 2 Working hours of each procedure.

Procedure	Effective working hours (h)
Concrete mixing operation	7
Reinforcement Cutting	8.5
Brick Crushing operation	6
Formwork	9

2.4.2 Health Risk Characterization

It has been consistently demonstrated by multiple studies that noise primarily leads to irreversible hearing loss and resulting in significant health impairments (Concha-Barrientos et al, 2004), (Li et al, 2016), (Liu, 2003). Consequently, the primary focus of this study is on hearing loss. Based on relevant studies (Concha-Barrientos et al, 2004), (Davis, 1989), and (Chen et al, 2020) Eq. (2.4.3) (Chen et al, 2020) used to define the health risk value due to noise pollution.

$$ER = (RR - 1) \times E_p \dots\dots\dots\dots (2.4.3)$$

Where ER is the estimated excess risks, RR is the relative risk due to occupational noise, and the E_pR is the expected risk due to occupational noise.

The ER values are presented in table 5, while RR and ($\boldsymbol{E_pR}$) can be found in Tables 3 and 4, respectively.

Table 3 Relative Risk (RR) according to age group and level of noise exposure (Chen et al, 2020).

	Age Group					
Level (dB A)	**15-29**	**30-44**	**45-59**	**60-69**	**70-79**	**>80**
<85	1.00	1.00	1.00	1.00	1.00	1.00
85-90	1.96	2.44	1.91	1.66	1.12	1.00
>90	7.96	5.62	3.83	2.82	1.62	1.00

Table 4 Expected risk ($\boldsymbol{E_pR}$) according to the age group (Chen et al, 2020).

Age	**15-29**	**30-44**	**45-59**	**60-69**	**70-79**	**>80**
Prevalence (%)	1.25	2.84	5.74	9.35	16.55	25.35

Table 5 Determined excess risks (ER) according to level of noise exposure (%) and age group.

Level (dB A)	**15-29**	**30-44**	**45-59**	**60-69**	**70-79**	**>80**
<85	0	0	0	0	0	0
85-90	1.2	4.08	5.22	6.17	1.99	0
>90	8.7	13.12	16.24	17.02	10.26	0

2.4.3 Health Damage Measurements

The number of years of premature death life loss and health loss due to noise exposure can be measured through effect and damage analysis. The measured results are called DALY (disability-adjusted life years) and can be calculated by Eq 2.4.4 (Chen et al, 2020). table 7.

$$DALY = \sum_i^I (N_i \times ER_i \times DW \times D) \dots\dots\dots\dots (2.4.4)$$

Where the N_i is the number of workers in the age group i, as shown in table 6 and ER_i is the additional damage value of noise exposure of workers in age group i. And the DW is the disability weight, which is 0.192 according to relevant study (Mathers et al, 2003). D represents the total construction duration which equal to 4a.

Table 6 Age distribution of workers in each procedure.

Procedure	**15-29**	**30-44**	**45-59**	**Total**
Concrete mixing operation	4	5	3	12
Reinforcement Cutting	1	3	0	4
Brick Crushing operation	3	3	1	7
Formwork	3	2	0	5

Table 7 Estimated disability-adjusted life years (DALY)

Procedure	**DALY**
Concrete mixing operation	1.145a
Reinforcement Cutting	0.10a
Brick Crushing operation	0.63a
Formwork	0

3.0 RESULT AND DISCUSSION

The intensity of noise pollution and its effect during construction work is the main focus of this study. Another key focus was examining the influence of noise exposure on construction workers during their working hours and over an extended period. A sound level meter was used to measure the noise levels in the project area. The noise levels, including the maximum, minimum, and average readings for various types of machinery and their tasks during a construction project, are indicated by the data presented in tables 8 to 16. The limits set by OSHA standards are exceeded by the noise generated by the current working operations.

Table 8 The maximum, minimum and average sound level of Project A at a distance of 1m, January 2023.

Type of activities	**Minimum (dB)**	**Maximum (dB)**	**Average (dB)**
Unloading Materials	53.3	65.2	59.3
Rod cutting	87.6	93.2	90.4
Loading garbage	61.2	66.5	63.9
Formwork	77.2	86.9	82.1
Plastering Work	59.3	70.1	64.7

Hand mixing of concrete	60.2	67.9	64.1

Table 9 The maximum, minimum and average sound level of Project A at a distance of 3m, January 2023.

Type of activities	Minimum (dB)	Maximum (dB)	Average (dB)
Unloading Materials	51.1	63.3	57.2
Rod cutting	83.9	90.4	87.2
Loading garbage	57.5	64.3	60.9
Formwork	71.6	82.2	76.9
Plastering Work	56.7	67.3	62.0
Hand mixing of concrete	56.8	64.7	60.8

Table 10 The maximum, minimum and average sound level of Project A at a distance of 5m, January 2023.

Type of activities	Minimum (dB)	Maximum (dB)	Average (dB)
Unloading Materials	49.0	59.6	54.3
Rod cutting	78.7	85.3	82.0
Loading garbage	51.3	59.6	55.5
Formwork	67.2	74.5	70.9
Plastering Work	50.1	61.2	55.7
Hand mixing of concrete	50.8	63.5	57.2

Table 11 The maximum, minimum and average sound level of Project E at a distance of 1m, January 2023.

Type of activities	Minimum (dB)	Maximum (dB)	Average (dB)
Unloading Materials	61.6	69.2	65.4
Water pumping	74.2	81.6	77.9
Soil Compaction	91.5	97.1	94.3
Concrete Mixing	93.9	97.2	95.6

Table 12 The maximum, minimum and average sound level of Project E at a distance of 3m, January 2023.

Type of activities	Minimum (dB)	Maximum (dB)	Average (dB)
Unloading Materials	57.3	64.7	61.0
Water pumping	71.5	77.1	74.3
Soil Compaction	84.2	91.8	88.0
Concrete Mixing	81.8	89.3	85.6

Table 13 The maximum, minimum and average sound level of Project E at a distance of 5m, January 2023.

Type of activities	Minimum (dB)	Maximum (dB)	Average (dB)
Unloading Materials	51.6	59.5	55.6
Water pumping	67.7	70.9	69.3
Soil Compaction	78.4	84.7	81.6
Concrete Mixing	77.8	82.3	80.1

Table 14 The maximum, minimum and average sound level of Project E at a distance of 1m, January 2023.

Type of activities	Minimum (dB)	Maximum (dB)	Average (dB)
Soil Excavation	91.5	98.4	94.9
Pickup loading	87.2	93.1	90.2
Front End Loader	89.3	91.7	90.5
Brick Crushing	92.2	97.0	94.6

Table 15 The maximum, minimum and average sound level of Project E at a distance of 3m, January 2023.

Type of activities	Minimum (dB)	Maximum (dB)	Average (dB)
Soil Excavation	84.7	92.2	88.5
Pickup loading	79.9	84.3	82.1
Front End Loader	81.4	86.7	84.1
Brick Crushing	89.8	94.0	91.9

Table 16 The maximum, minimum and average sound level of Project E at a distance of 5m, January 2023.

Type of activities	Minimum (dB)	Maximum (dB)	Average (dB)
Soil Excavation	80.2	86.1	83.2
Pickup loading	75.4	79.7	77.6
Front End Loader	77.9	82.1	80.0
Brick Crushing	86.5	89.9	88.2

The table showed sound level induced in ILST, Sylhet mentioned above indicates that the noise levels tend to decrease as far away from loud noise-producing machines as possible. And it

also analyzed that in construction site heavy machinery is responsible for most of the loud noise generation such as roller, brick crushing machine, concrete mixing machine, front-end loader, steel bar cutting machine etc.
Noise pollution is a significant concern, impacting worker health, safety, communication, and productivity. Although noise levels over 85 dBA during construction activities are harmful to workers and neighbors, most of the time (about 23%) construction sites exceed 90 dBA noise levels, affecting the normal life of neighbors (Wami, 2021). Construction management should include noise mitigation planning (Gayathri et al., 2024).

3.1 Analysis of Sampling Results

Through the on-site noise intensity measurement, the noise exposure of the workers under different operations is determined according to Eq. 2.4.1 are shown in Table 17.

Table 17 The results of noise exposure of ILST, Sylhet

Procedure	Noise Source	$L_{A,1m}$	$L_{A,3m}$	$L_{A,5m}$	$L_{A,eq}$	$L_{EX,8h}$
Concrete Mixing operation	Concrete mixing machine	95.6	85.6	80.1	91.4	90.8
Rebar Cutting operation	Rebar cutting machine	90.4	87.2	80.0	87.7	88.0
Brick Crushing operation	Brick Crusher	94.6	91.9	88.2	92.3	91.1
Formwork	Hammering , Adjusting	82.1	76.9	70.9	78.7	79.2

From Table 17, The noise generated by concrete mixing and brick crushing exceeded the 90 dB (A) limitation set by the Ministry of Transport PRC in 2009. This was mostly caused by the operation of large-scale machinery. Among all procedures, the workers in the brick-crushing operation suffered the most noise exposure (91.1 dB (A)). Furthermore, the noise exposure level due to rebar cutting operation cross the noise level of 85 dB (A). However, the noise exposure level of formwork was 79.2 dB (A).

3.2 Health Damage Analysis

Substitute the values into Equations (2.4.1) to (2.4.4) to calculate the impact of noise pollution on workers' health during the ILST construction project, as illustrated in Figure 5. The figure depicts that the 4-year construction project will cause significant noise pollution for all workers. The overall health damage is estimated to be 1.875a, of which concrete mixing will experience the most severe total health damage, with a DALY of 1.145a. On the other hand, the noise level in the Formwork is very marginal (72.2 dB (A)), which is insufficient to cause any serious damage on the workers' health. The graph also shows that the health damage value for rebar cutting operation and brick crushing operation was 0.10a and 0.63a respectively.

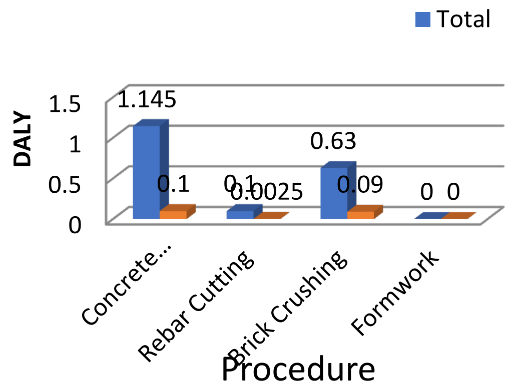


Figure 5 Comparison of health damage in each procedure

In all cases except for brick crushing, per capita damage was consistent with total damage. The main reason is that even though brick crushing makes more noise than mixing concrete (Table 1), the damage done per person is almost the same because of the minimum number of workers. However, per capita health damage of rebar cutting procedure was least of all.

3.3 Analysis of Noise Induce Hearing Loss (NIHL)

Noise-induced hearing loss (NIHL) is the result of exposure to hazardous and loud noise. It can affect people of all ages and may be either temporary or permanent. This analysis was performed based on the audiogram report provided by hearing diagnostic center. An audiogram is a graphical representation of hearing sensitivity, with frequency plotted on the abscissa and intensity plotted on the ordinate (Kutz, 2023).

A worker named "Delwar Hossain" was tested in the Audiometry Lab in Sylhet, Bangladesh. He was tested for first attempt in January 2023. The following audiogram report shows the workers pure tone audiometry test value of pure tone average (PTA). Pure-tone average (PTA) is the average of hearing sensitivity at 500Hz, 1000Hz, 2000Hz and 4000Hz. This average should be within 5 dB of the Speech Reception Threshold (SRT) and 6 dB to 8 dB. The SRT refers to the minimum intensity level at which an individual may correctly repeat spondee words at least 50% of the time (Kutz, 2023). The speech detection threshold (SDT), also known as the speech awareness threshold (SAT), is the lowest-intensity speech stimulus that an individual can detect at least 50% of the time (Kutz, 2023).
The pure tone audiometry test was performed for both ears separately. When Delwar Hossain was tested for 1st attempt, he was engaged in reinforcement barging and cutting work with 5 years of continuous experience with different sectors in construction work.

The following Figure 6 Audiogram report shows the hearing sensitivity condition of right ear provided by audiometrist that was performed in January 2023.

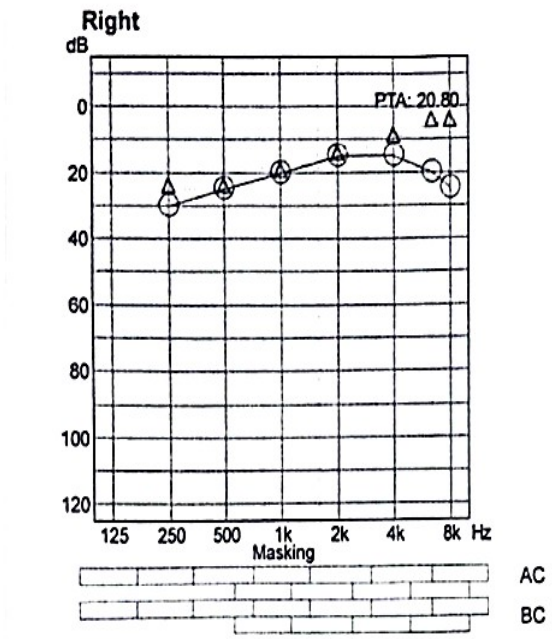


Figure6 Audiogram Report of Right Ear -Delwar Hossain

This test was performed in the audiometry lab with digital audiometer with manual input facilities of sound frequency. Pure tone average (PTA) value 20.8 dB for the right ear of the examined construction worker were analyzed and compared with Table 1, found that the average intensity level was plotted in the range of *Slight hearing loss*. Hence audiogram report analyzed and found the right ear of construction labor experienced slightly hearing loss.

The following Figure 7 Audiogram report shows the hearing sensitivity condition of left ear provided by audiometrist that was performed in January 2023.

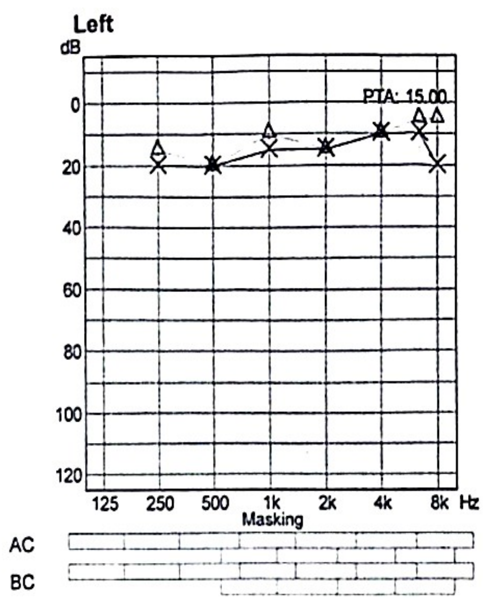


Figure 7 Audiogram Report of Left Ear -Delwar Hossain

Same analyzing process was also performed for the left ear audiogram report shows in Figure 7 and found that the PTA value was 15.00 which is in the range of Normal hearing level according to table 1. Hence analysis of audiogram for left ear showed the Normal hearing level. The bone conduction report for right and left ear (Figure 6 and Figure 7) was analyzed as the same process and noted that the intensity level was 25dB, 20dB, 15dB and 10dB for the frequency of 500Hz, 1000Hz, 2000Hz and 4000Hz respectively, while the specific frequency of 500Hz the hearing level was 25dB which is in the range of slight hearing loss degree and others were in the normal hearing level (Clark, 1981).

A similar analysis was performed for another worker named Ramim Ahmed. When he was tested for 1st attempt, he was engaged in concrete mixing machine operation. The following Figure 8 Audiogram report shows the hearing sensitivity condition of right ear provided by the audiometrist that was performed in January 2023.

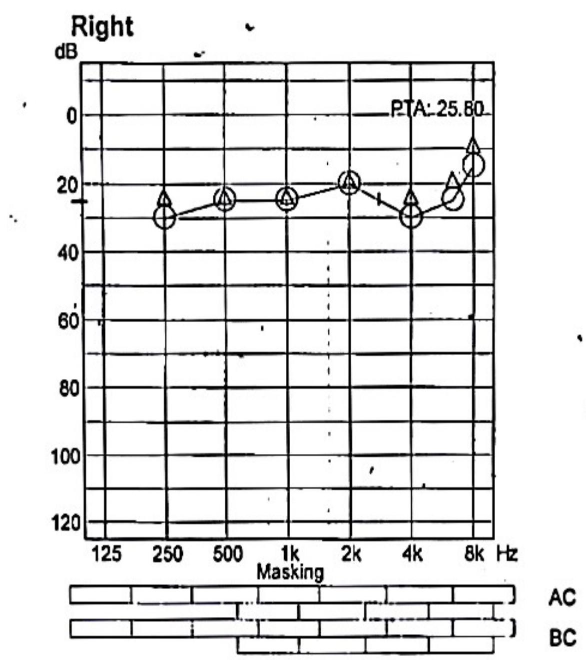


Figure 8 Audiogram Report of Right Ear -Ramim Ahmed

The right ear audiogram report shows in Figure 8 and found the PTA value was 25.80 which crosses the range of Slight hearing loss. This report showed that the worker experienced Mild Sensorineural hearing loss. Further analysis of audiogram for the left ear shows in Figure 9 the PTA value was 20.80 which is not in the range of HL -10dB to 15dB i.e. Normal hearing level. 20.80dB was plotted in *the Slight hearing loss range i.e. 16dB to 25dB.*

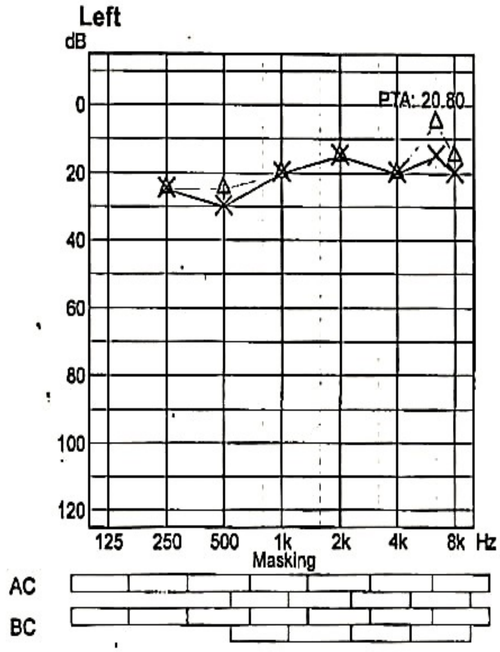


Figure 9 Audiogram Report of Left Ear -Ramim Ahmed

Further analysis was performed for both selected construction workers named “Kawser Ahmed” and “Rasel Ahmed”. Additionally, found the PTA value 20.80 dB and 18.30 dB for right ear. For the right ear of those two workers the audiogram reports showed in the Figure 10 and Figure 11 the PTA value of Kawsar and Rasel 20.00 and 20.00 respectively. After the exploration of these data and compared with Table 1 found that they both were experienced *Slight hearing loss*.

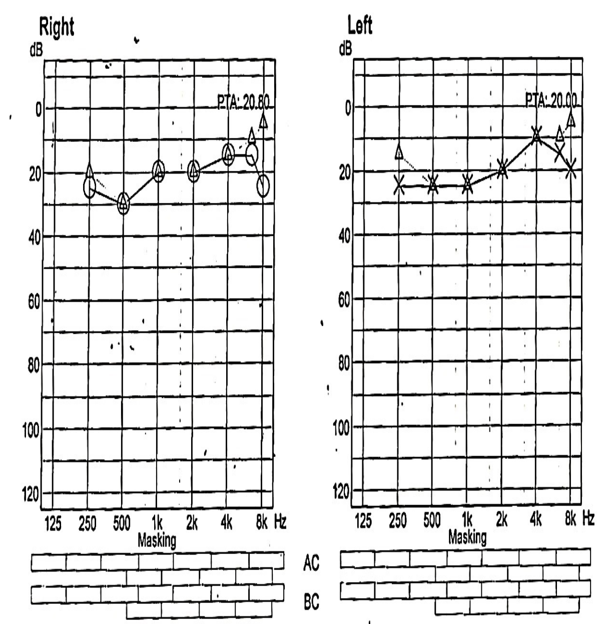


Figure 10 Audiogram Report of Right & Left Ear -Kawsar Ahmed

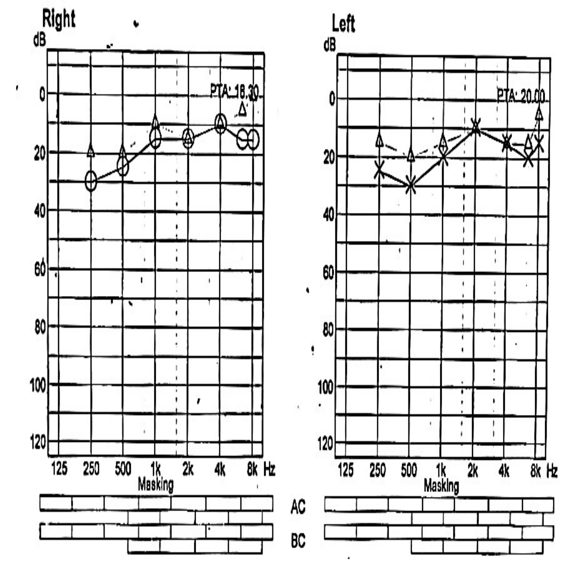


Figure 11 Audiogram Report of Right & Left Ear -Rasel Ahmed

After a waiting period of almost 205 days the hearing test was performed for 2nd time. In the Second attempt two construction workers were tested and their audiogram report was provided by the audiometrist.

The following Figure 12 Audiogram report shows the hearing sensitivity condition of right & left ear provided by audiometrist that was performed in August 2023.

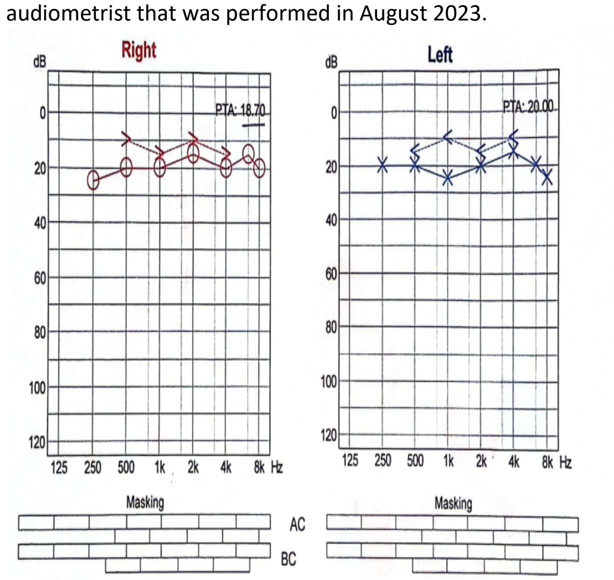


Figure 12 Audiogram Report of Right & Left Ear -Delwar Hossain

The audiogram report shows in Figure 13 was analyzed and found that the value of Pure Tune Average for right and left ear were 18.70 dB and 20.00 dB respectively which crosses the normal hearing level. According to table 1 both PTA value is plotted in the range of slight sensorineural hearing loss.

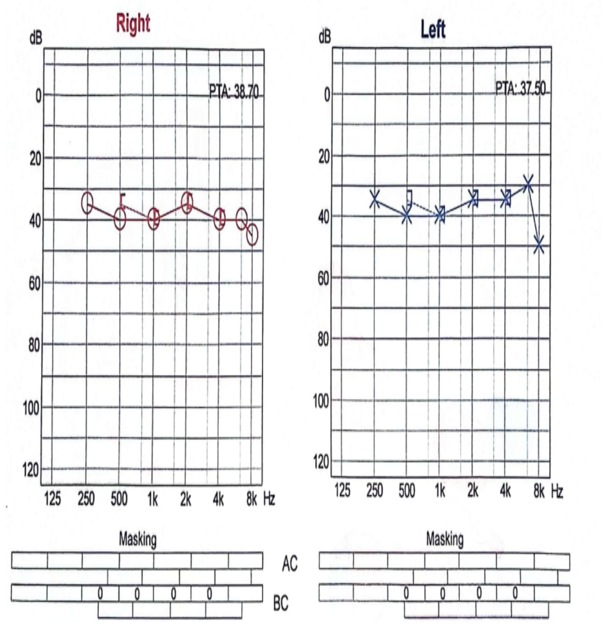


Figure 13 Audiogram Report of Right & Left Ear -Ramim Ahmed

The above audiogram report illustrates the hearing sensitivity condition of right & left ear of "Ramim Ahmed". The PTA vale found from the test was 38.70 dB and 37.50 dB for both ears respectively. This report showed that the worker experienced Last stage of Mild hearing loss (Table 1).

3.3.1 Comparisons between Two Attempts

The following Figure 14 shows the comparison of hearing level of right ear between the two attempts of worker "Delwar Hossain" taken at January 2023 and August 2023.

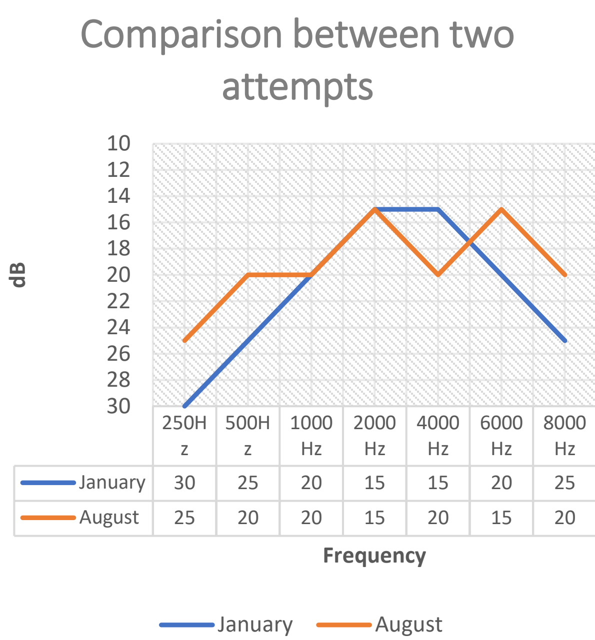


Figure 14 Comparison of Right Ear HL between two attempts -Delwar Hossain

The following Figure 15 shows the comparison of hearing level of left ear between the two attempts of worker "Delwar Hossain" taken at January 2023 and August 2023.

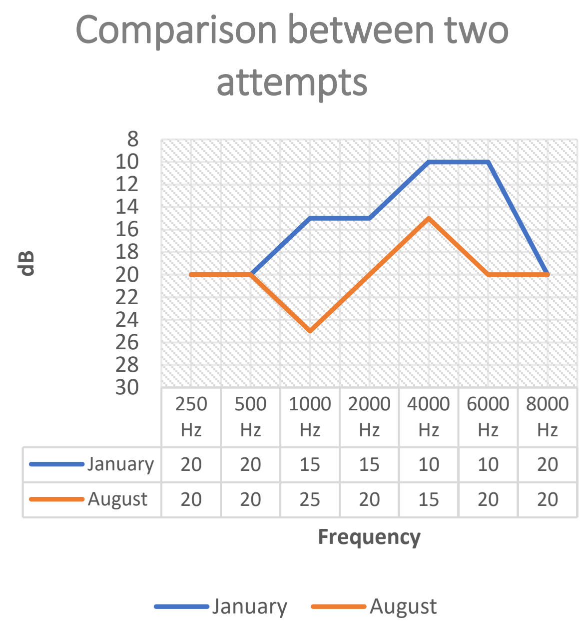


Figure 15 Comparison of Left Ear HL between two attempts -Delwar Hossain

The following Figures 16 and 17 shows the comparison of hearing level of right and left ear respectively between the two attempts of worker "Ramim Ahmed" taken at January 2023 and August 2023.

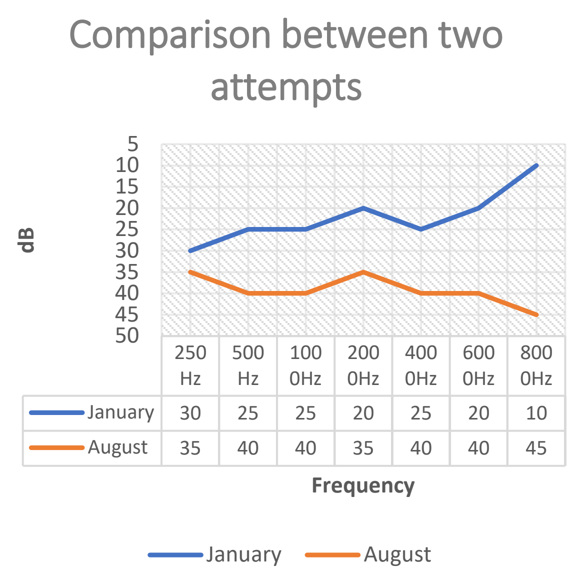


Figure 16 Comparison of Right Ear HL between two attempts -Ramim Ahmed

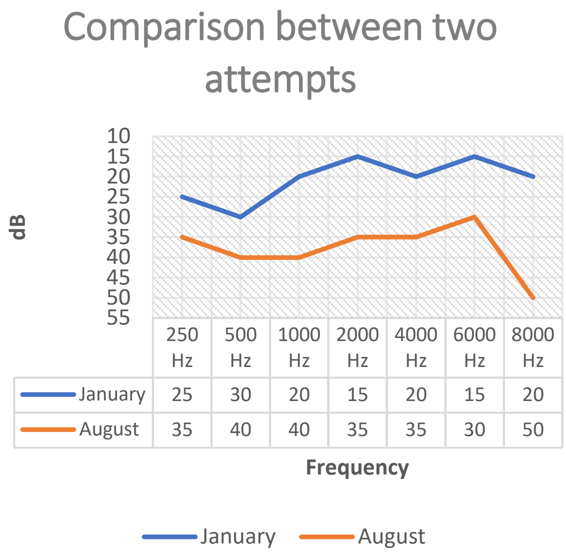


Figure 17 Comparison of Left Ear HL between two attempts -Ramim Ahmed

4.0 CONCLUSION

Workers in construction projects are exposed to unwanted noise. Those who work continuously for a long time in a high-noise environment are especially exposed to problems related to noise pollution which impairs the ability to communicate. Hearing aids may help, but they are not a solution for restoring hearing to normal. Although the implementation of noise barriers can be effective, it is imperative to consider noise mitigation strategies in every mega project and project in urban cities. It is observed that the effects of construction noise are overlooked by the construction industry in urban areas. Moreover, the risks associated with construction noise pollution are not properly addressed. A strategic policy framework, including worker training regarding safety and communication, is recommended to mitigate the adverse effects of noise pollution, enhance the resilience of the construction industry, improve overall working efficiency, and ensure workers' safety, aligning with sustainable development goals.

The main conclusions of this study are mentioned below:

a. Analyzing the results of the Pure Tune Audiometric tests report of the workers showed that regular involvement in construction work resulted in more than normal hearing loss.
b. Construction workers involved in excessive noise levels are comparatively more affected by noise-induced hearing loss than the workers who experienced lower noise.
c. In ILST, Sylhet construction project, due to close proximity to the construction environment and loud noise-generating equipment, the construction workers experienced fatal noise pollution, resulting in a considerable amount of health damage (DALY= 1.145a). Regarding total health damage, concrete mixing is the activity that is most harmful with a DALY value of 1.145a, which is almost 1.82 times of the brick crushing. In addition, the workers who cut the rebar experienced less health damage. In contrast, the damage in the rebar-cutting procedure is minimal (DALY=0.0025a), while formwork is zero. However, the health damage caused by various working activities is not the same; it is influenced by effective working hours and the number of workers.

To reduce the impact of noise exposure, workers should be required to wear suitable safety devices, for example noise-cancelling headphones or earplugs, or other hearing protection devices designed to reduce noise levels effectively. Regular monitoring and awareness programs should be implemented to educate workers about the importance of hearing protection in preventing long-term auditory damage.

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Conflicts of Interest

The author(s) declare(s) that there is no conflict of interest regarding the publication of this paper

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