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Assessment of Noise Levels in a Construction Site: A Case Study

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ABSTRACT

A study was conducted at a construction site to assess noise levels at various locations during operational hours. Using a digital sound level meter, the maximum sound level was measured near the piling mixer, contrasting with the minimum intensity recorded away from any sound source. The overall average sound level was 87.03 dBA. This high noise level poses a risk of serious hearing impairment. To mitigate this issue, Active Noise Control (ANC) and Passive Noise Control (PNC) methods can be employed. The theoretical analysis of the sawdust composite sound shield reveals a promising reduction, ranging from 40.24 dBA to 70.68 dBA, ensuring compliance with standard sound levels in various areas. The research strongly recommends the adoption of passive noise control, specifically through the use of natural composites. It emphasizes the urgent implementation of measures to protect the health of construction workers and surrounding residents by covering noise sources.

1. Introduction

Noise is an unwanted sound considered unpleasant, loud, or disruptive to hearing which is undistinguished from desired sound [1-5]. Noise pollution occurs when the noise level exceeds a certain limit and has deleterious effects on human health and environmental quality in an ecosystem [1]. Alam et al. (2016) conducted a study measuring noise in six industries during April, May, and June 2013. Recorded at various locations, daytime noise levels exceeded DoE standards: textile mill (81.50 dB), cotton mill (104.20 dB), jute mill (90.50 dB), spinning mill (95.90 dB), knit and garments factory (89.25 dB), and knitting factory (83.50 dB). Industrial noise pollution, mainly from machines and worker density, led to health issues. The study suggested replacing noisy machines to address the problem. Unfortunately, specific solutions were not provided [6]. Owoyemi et al. (2016) revealed that the air hammer registered a peak noise level of 110 dBA, posing health risks such as hearing impairment, sleep disturbances, and cardio-metabolic disorders. The study emphasized measuring noise levels rather than addressing control or reduction strategies. Limited to wood industries, the paper provides insights into the overall noise pollution conditions in these industries and their impact on workers, though it does not offer solutions for noise mitigation [7]. Gongi et al. (2016) reported that noise in informal metal industries, professional metal industries, and grain processing plants, exceeding 90 dBA, led to a 7% decrease in hearing, 36% increase in migraines, 19% buzzing in the ears, 15% irritability, and 9% lack of sleep among

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workers. The study, however, did not propose solutions for these negative effects. While offering insights into Nairobi's overall noise conditions, the findings may be applicable to other countries as well [8]. Chowdhury et al. (2014) measured noise levels at over 50 sites, revealing the highest average noise level to be 104.5 dBA. The study method involved selecting a study area, collecting data, measuring sound levels, and determining their average. However, no solutions were provided. The paper offers insights into the conditions of the municipal area studied, contributing to an understanding of the overall noise environment [9]. Noweir et al. (2014) conducted a study in metalwork and woodwork industries at 28 randomly selected factories in Jaddah Industrial Estate, noting the highest noise levels exceeding 90 dBA. Their approach involved selecting, measuring, and analyzing the noise levels of these factories, focusing solely on measurement rather than noise reduction or associated health risks for workers. However, the paper provides insights into the noise pollution scenario in Saudi Arabia [10]. Salehin et al. (2014) focused on the average highest and lowest sound levels in eight industries in Chittagong City, ranging from 77.26 to 96.53 and 67.71 to 86.62 dBA, respectively. The study involved selecting the study area, collecting data, measuring noise levels with a noise level meter, and subsequent data analysis. The research primarily concentrated on measuring noise and its risk factors for workers, without addressing the reduction or elimination of noise pollution [11]. Stephen et al. (2013) measured noise levels in four manufacturing companies and from 98 workers, with the hammer mill registering the highest level at 108.5 dB. Employing a sound level meter, the study focused on measuring noise without proposing solutions to minimize unwanted noise pollution. Although the research did not address the mitigation of noise, it provided insights into the pollution's impact on workers' health [12]. Abbasi et al. (2011) investigated 40 units of various textile mills, noting the highest noise value of 108.7 dBA in Category-D. Workers in this category reported irritational (33%), listening (53%), respiratory (43%), heart (28%), annoyance (48%), regular headache (40%), and occasional headache (43%) problems during working hours. The study employed proper procedures and a digital sound level meter for data collection but focused on measuring and identifying effects on workers rather than proposing solutions to reduce the problem [13]. Oyedepo, O. S. et al. (2009) mentioned that they had selected a total number of 47 locations and industrial sites. The highest sound pollution level was 110.2 dBA. They did this process by selecting a study area then the noise survey was happened with time-varying noise exposure. After that they analyse it. They also did not find a way to overcome this issue [14]. Boateng et al. (2004) measured noise levels in sawmills, corn mills, and printing houses, noting a mean sound level of 85 dBA in the printing site, where hearing impairment was observed. Following a similar methodology as previous authors, the study did not address the reduction of unwanted noise. Additionally, it solely concentrated on the three mills, without exploring noise issues in construction sites or other industries [15]. Akpan, A. O. et al. (2003) claimed that the highest measured value was 119.5 dBA at the industry in Akwa Ibom State and also revealed that 96% of the workers assessed wanted industrial noise to be controlled and abated. They did not pay heed to the controlling of this pollution [16]. Agbo et al. investigated the acoustic characteristics of the TG950 generator and presented a full-scale acoustic enclosure design. Treating the generator as a point source, the study demonstrates a substantial 17% noise reduction with the designed enclosure, optimal at a stack height of 1600 mm. Exhaust tunnelling beyond 200 mm shows negligible improvement. The research emphasizes the enclosure's effectiveness in reducing noise pollution, ensuring operational safety, and protecting users from harmful generator fumes, offering a comprehensive solution for various environments [17]. Pardo-Quiles et al. (2020) revealed the acoustic performance of noise barriers with attached caps, focusing on various shapes and configurations. Y-shaped single and double caps prove most effective, reducing noise by about 14 dB. The inclusion of absorbing materials further enhances performance. Simultaneous use of sloping grounds and double Y caps provides the best results, with an additional sound pressure level mitigation of 6–7 dB. The study advises against indiscriminate increases in diffraction elements and outlines plans for future research, including exploring diffracting structures and the impact of absorbing materials [18]. Gieva et al. (2018) reported the impact of construction barrier thickness and profile radius on the noise reduction effectiveness of a passive traffic noise barrier. Numerical modelling and simulations, validated by experimental setups, reveal that thickness has minimal effect, while optimal acoustic performance is achieved with a half-pipe radius of 500-600 mm. The best acoustic performance within the studied frequency range is obtained at a pipe radius of 500 mm. The size of profiles significantly influences acoustic response, and through the synthesis of profile diameter, maximum noise isolation can be attained. This study guides future considerations in optimizing barrier design for practical noise reduction applications [19]. Liu et al. (2015) discussed the implementation of active and passive noise control technologies in existing sound insulation windows to address low-medium frequency noise. Experimental results reveal over 15 dBA additional noise reduction at low-medium frequency with active control and more than 10 dBA extra reduction at medium-high frequency with passive control. The integrated window achieves a total of 42 dBA noise reduction while ensuring natural ventilation [20]. Monazzam-Esmaeelpour et al. (2013) addressed noise pollution in the Iranian knitting industry (2009). The study employs environmental noise assessment to estimate overall noise levels at the Sina Poud textile mill. The study revealed a range of sound pressure levels, with the highest at 98.5 dB and the lowest at 95.1 dB. The dominant frequency in the industry was identified as 500 Hz. Sound suppression interventions demonstrated the highest impact at 4000 Hz, achieving a reduction of 14.6 dB, and at 250 Hz in the textile industry. The study concludes that increasing workplace absorptive surfaces, using materials like polystyrene, is a viable strategy when source control is challenging [21].

These investigations highlight the issue of noise pollution and its adverse impact on both humans and animals, underscoring the importance of implementing noise reduction measures. Also, these studies contribute to the understanding and implementation of effective noise control strategies across diverse environments and industries. Hence, it is necessary to formulate a strategy to decrease noise levels to a tolerable limit.

This work endeavours to assess noise pressure levels at various locations inside the construction site in front of the Fitting Shop at Rajshahi University of Engineering & Technology (RUET), with a focus on understanding the impact of noise pollution on worker health. Then, the study recommends the implementation of a Passive Noise Control (PNC) solution, specifically advocating for the use of sound shields, to effectively reduce noise and enhance the well-being of workers in the construction site environment as well as the dwellers who live surrounding these sound sources.

2. Materials and methods

2.1. Study area

The study was conducted in the vicinity behind the machine shop at RUET, where construction activities were underway on an area of approximately measuring (100 x 60) m², totalling around 6000 m² (Fig. 1).

Figure 1. Study area

(Source: Google Maps in satellite view)

2.2. Selection of locations and data collection

Initially, the study area was surveyed and segmented into 20 locations using a measuring tape during the evening when construction activities were concluded for the day. The following morning at 8 am, as construction resumed and all machinery in the area became operational, measurements were taken using a digital sound level meter. If any of the machinery temporarily ceased operation, data collection was paused accordingly. This is why it took three hours to gather data from all 20 locations. Noise levels were assessed at 20 locations following standard procedures, utilizing a digital sound level meter between 8:00 AM and 11:00 AM (Fig. 2). Simultaneously, the Android Weather Application recorded the average temperature, humidity, and air velocity at 29°C, 79%, and 11.4 km/h, respectively. Six machines operated simultaneously during the measurements. Primary data were gathered from the 20 locations using a digital sound level meter positioned 1.5 m above the ground because the average heights of Bangladeshi females and males are 1.503 m and 1.621 m respectively and the human ear is located a few centimetres below the top of the human body, while secondary data were sourced from various relevant outlets and online information.

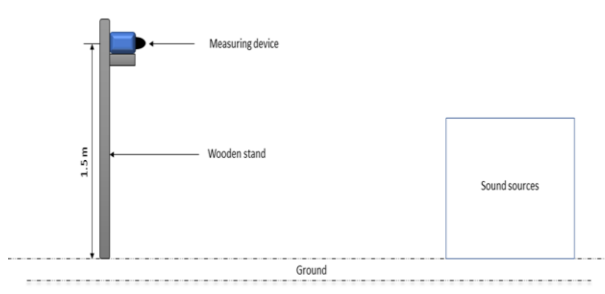

Figure 2. Schematic diagram of the process for taking data

2.3. Sound level meter

In this investigation, the shi-bd model is utilized—a recently introduced ABS sound level meter with a measuring range of 30-130 dBA and an accuracy of ±1.5dB (Fig. 3). It includes a 4-digit digital display, 0.1dB resolution, and supports both A and C frequency weights. Powered by a 9V battery, it operates for approximately 30 hours, features fast and slow reaction rates, and has dimensions of 149 x 57mm. Equipped with a ½-inch capacitive microphone, overload indication, and versatile output choices, it functions under conditions of 0-40°C, 10-80% RH, with storage conditions at -10-60°C, 10-70% RH. It comprises a calibrated microphone, electronic circuits, and a display, which was utilized to measure the noise level. The microphone detected pressure variations in the sound field, converting them into electrical signals. These signals were processed by electronic circuitry to measure the desired characteristics, subsequently displayed on an LCD in decibels (dBA). For this study, a digital sound level meter was employed for noise level measurements.

Figure 3. Digital sound level meter

2.4. Locations and status of noise sources

In the specified study zone, twenty distinct measurement locations, designated as Points 1 to 20 (refer to Fig. 4), were pinpointed to conduct comprehensive evaluations of sound pressure levels. The accompanying visual depiction in Fig. 5 vividly illustrates the existence of noise-emitting sources situated within the construction site, visually represented by red objects discernible in Fig. 4. This strategic identification and mapping of measurement points contribute to a thorough examination of the sound environment, aiding in the assessment and understanding of noise sources in the designated area.

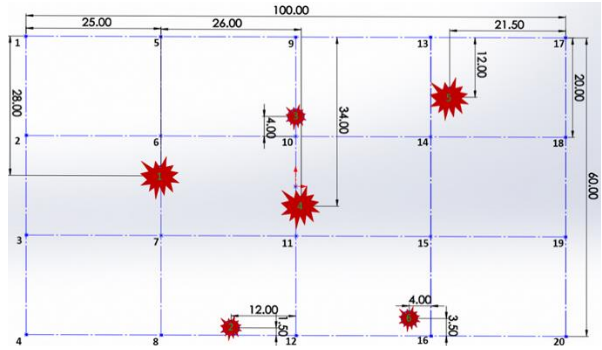

Figure 4. Locations in the study area with marking points and distance in metres

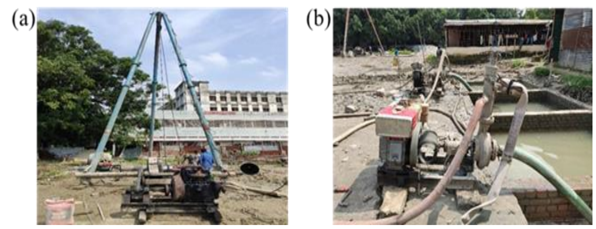

Figure 5. (a) Piling & mixing machine, and (b) water pump machine

Table 1. The running condition of the different types of noise sources

No. of sources	Name of the sources	States of sources
1	Piling and mixing machine	Running
2	Water pumping machine	Running
3	Water pumping machine	Running
4	Piling and mixing machine	Running
5	Piling and mixing machine	Running
6	Water pumping machine	Running

A total of six machines, specifically Piling and Mixing Machines, along with Water Pumping Machines (as detailed in Table 1), constituted the identified noise sources. The deliberate arrangement of these machines throughout the construction site played a pivotal role in influencing the observed fluctuations in noise levels across various measurement points. This strategic deployment sheds light on the significant impact of machine placement on the overall noise environment within the construction site.

2.5. Determination of sound pressure in Ansys Inc.

2.5.1. Geometry

A three-dimensional computer-aided design (3D CAD) model was meticulously crafted using the SOLIDWORKS 2020 version, as illustrated in Fig. 6. The specimen barrier's dimensions were precisely defined, featuring a thickness of 10 mm and a height of 240 mm. The internal space within the barrier measured 240 mm in width, 240 mm in depth, and 240 mm in height, accommodating an 80 mm diameter and 60 mm height speaker positioned at the centre. The detailed specifications were instrumental in creating an accurate and comprehensive representation of the designed structure.

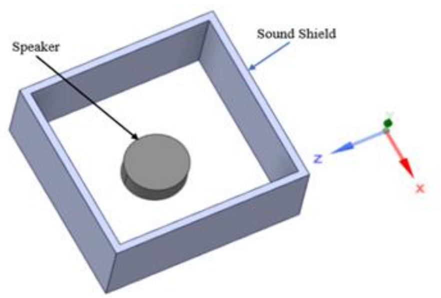

Figure 6. 3D model of speaker and sound shield for the simulation

2.5.2. Steps for simulation at Ansys Inc.

In the initial step, Harmonic Acoustics was chosen upon launching Workbench 2022 R1. Subsequently, engineering data was modified, incorporating information about the sawdust composite material. The geometry of the model was obtained from an external source, specifically a SOLIDWORKS IGS file, and further refined using SpaceClaim through the selection of Enclosure & Share. Following this, various aspects of the model were adjusted, including Geometry, Analysis Settings, Acoustics Region, Physics Region, Mass Source, Fluid Solid Interface, Radiation Boundary, Mesh, and Coordinate Systems. To conclude the simulation process, the "solve" option was selected, focusing on the sound pressure level as the desired output for the specific solution.

2.5.3. Sound pressure level

Within this segment of the study, a comprehensive evaluation of the properties and behaviour of three distinct materials was conducted through simulation. The materials under consideration encompassed air, PVC plastic, and sawdust composite. For Air and PVC plastic, predefined parameters were utilized from the Ansys Inc. built-in library. In contrast, the assignment of properties for sawdust composite involved a manual process because this composite was fabricated in the Metrology laboratory, RUET, wherein Density (1628 kg/m^3), Poisson Ratio (0.25), and Young's Modulus (5x10^6) were considered key factors in the characterization of their behaviour within the simulation.

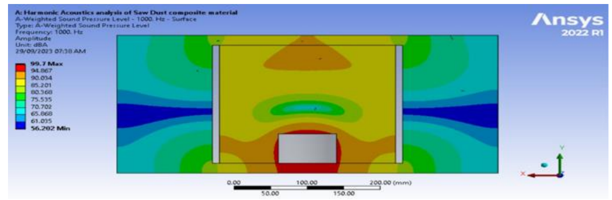

Figure 7. Sound pressure level at the enclosure for 1000 Hz

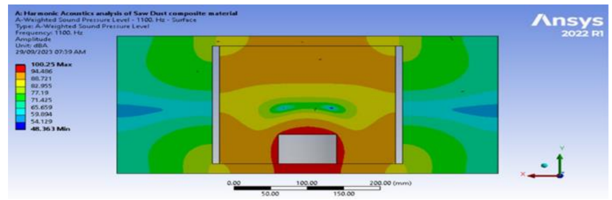

Figure 8. Sound pressure level at the enclosure for 1100 Hz

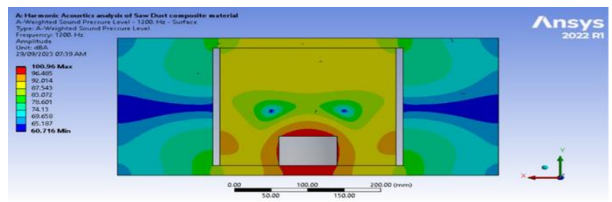

Figure 9. Sound pressure level at the enclosure for 1200 Hz

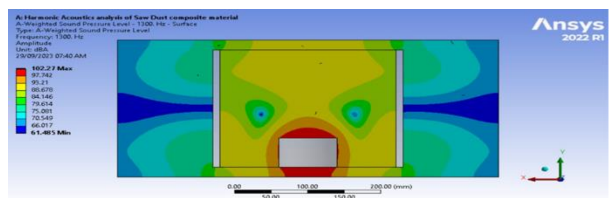

Figure 10. Sound pressure level at the enclosure for 1300 Hz

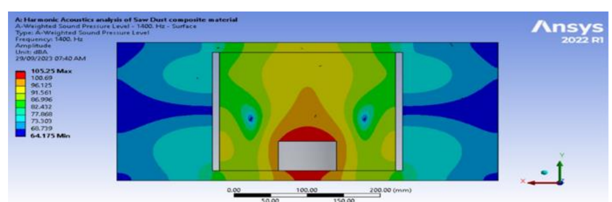

Figure 11. Sound pressure level at the enclosure for 1400 Hz

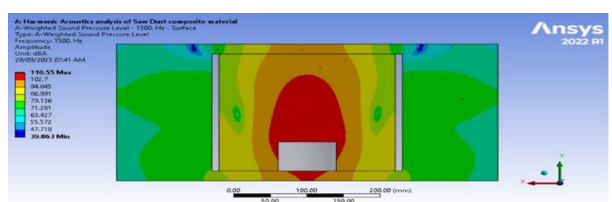

Figure 12. Sound pressure level at the enclosure for 1500 Hz

Figs. 7 to 12 provide a detailed representation of sound pressure levels within the enclosure, offering insights into the propagation of sound waves. Within these illustrations, both maximum and minimum sound pressure levels are depicted. An observable trend is noted in the maximum levels, which exhibit an upward trajectory as frequencies escalate from 1000 Hz to 1500 Hz. Conversely, minimum levels showcase a fluctuation within the range of 1000 Hz to 1500 Hz. This detailed analysis reveals that maximum sound pressure levels consistently increase with rising frequencies, while minimum levels exhibit variations rather than a consistent decrease across the frequency spectrum. The sound pressure level consistently remains within acceptable and tolerable limits throughout the specified conditions or parameters.

3. Results and discussion

Examining Fig. 13, it is evident that the maximum recorded sound pressure level reached 97.70 dBA, specifically in close proximity to the piling mixer machine. In contrast, the minimum noise level of 71.10 dBA was documented at a location significantly distant from any identifiable noise source within the same figure. On average, the overall noise level observed at the site during working hours amounted to approximately 87.03 dBA. The primary sources of noise were identified as a piling and mixing machine, as well as a water pump machine (refer to Fig. 5). Notably, the piling mixing machine emerged as the predominant contributor to noise, with the sound pressure level near the water pump machine registering the highest among all noise sources.

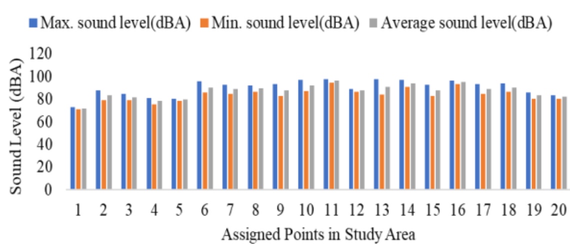

Figure 13. Noise levels at 20 points in study area

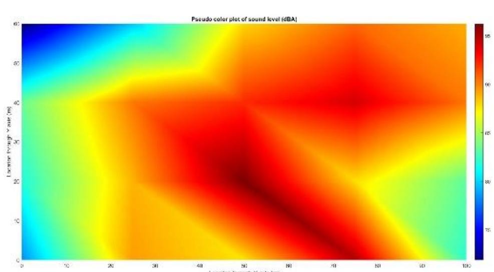

Figure 14. Pseudo-color plot of the data

Analysing Fig. 14, it becomes apparent that the central region of the construction site showcased elevated pollution levels compared to the rest of the study area. This observation implies that the sound pressure level was more pronounced in close proximity to the identified sound sources, gradually diminishing as one moved away from them. The figure thus highlights the spatial distribution of sound pressure levels within the construction site, emphasizing the concentration of noise near the primary sources.

Table 2. The standard noise level limits in Bangladesh [6]

SI no.	Category of areas	Sound levels (dB)	
		Day time	Night time
1	Silent zone	45	35
2	Residential area	50	40
3	Mixed area (mainly residential area and also simultaneously used for commercial purposes)	60	50
4	Commercial area	70	60
5	Industrial area	75	70

(Source: Department of Environment, 2004 Bangladesh)

The average noise level at the specified location during working hours is approximately 87.03 dBA, as indicated by the measurements. It's noteworthy that this level surpasses the acceptable noise standard for mixed areas during the daytime, which is set at 60 dBA, as detailed in Table 2. This comparison underscores the substantial deviation between the observed noise level and the established acceptable limit for the given environmental context.

Table 3. The noise level and their impacts on humans according to the doctors [6]

Noise level	Description
0 – 20 dB	Normal
20 – 45 dB	Mild hearing loss
40 – 67 dB	Moderate harmful
70 – 100 dB	Serious hearing loss
>100 dB	Acute health hazard

(Source: J. Environ. Sci. & Natural Resources, 9(2): 155-160, 2016 ISSN 1999-7361)

Examining the noise levels at different points, the recorded maximum and minimum values spanned from 71.10 dBA to 97.70 dBA. Notably, the highest noise level of 97.70 dBA was observed at the 11th measurement point, indicating its proximity to a significant sound source. The calculated average noise level across all points was 87.03 dBA, falling within the range of 70-100 dB, a spectrum associated with the potential for causing serious hearing loss, as outlined in Table 3. This detailed analysis provides insights into the variability and potential impact of noise levels at specific points within the studied area.

The theoretical analysis of the sound pressure levels of the sawdust composite sound shield, conducted within the frequency range of 1000 Hz to 1500 Hz, reveals promising results. The analysis indicates that this composite sound shield is capable of achieving a maximum reduction of 70.68 dBA at 1500 Hz and a minimum reduction of 40.24 dBA at 1200 Hz. Considering the prevailing standard sound pressure level of 60 dBA, 70 dBA, and 75 dBA in the mixed, commercial, and industrial areas respectively in the daytime, the analysis demonstrates that, post-noise reduction, the sound pressure levels for every frequency falls below this threshold. This suggests that the natural composite sound shield exhibits significant efficacy in mitigating sound, effectively creating an acoustic barrier that shields the environment from the adverse effects of noise. The findings underscore the potential of the sawdust composite sound shield as a valuable solution for noise control in construction sites as well as industrial settings.

4. Conclusions

The primary focus of this study is to assess noise levels at construction sites and understand their impact on workers' and residents' health, while also exploring effective strategies for sound pollution management. The findings underscore the urgent need for sound pollution control measures, especially in industrial and construction sites where noise pollution is often neglected. With an average recorded noise level of 87.03 dBA, the study highlights the severity of the issue and potential health risks for workers such as serious hearing loss. Despite being a substantial environmental concern, noise pollution often receives less attention than other forms. This study emphasizes the importance of prioritizing noise reduction efforts and exploring strategies to create quieter and healthier environments for those exposed to construction-related noise. The research identifies the effectiveness of natural composite sound shields, particularly those incorporating sawdust, as a promising approach to addressing sound pollution and enhancing living and working conditions. The composite sound shield achieves a maximum reduction of 70.68 dBA at 1500 Hz and a minimum reduction of 40.24 dBA at 1200 Hz, ensuring sound levels below standard thresholds in diverse areas. The innovative use of readily available materials emerges as a pivotal factor in mitigating noise pollution and contributing to an improved overall quality of life for workers and the broader community.

In response to these challenges, several recommendations are proposed. Firstly, the adoption of the ANC method can be a viable solution. Additionally, the PNC method is suggested as an effective choice. Combining both ANC and PNC methods is advocated to achieve a comprehensive approach to pollution reduction.

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