International Review of Practical Innovation, Technology and Green Energy (IRPITAGE) | ISSN (e): 2808-8611
Volumes 6 No. 2 (2026)

INDUSTRIAL NOISE MANAGEMENT STRATEGY BASED ON AN ENVIRONMENTAL MANAGEMENT SYSTEM IN THE GLASS PROCESSING INDUSTRY OF BEKASI CITY

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Received : 03 June 2026 Accepted : 25 June 2026
Revised : 09 June 2026 Published : 27 July 2026

Abstract

The development of the glass industry has the potential to increase environmental noise, which may affect the health of workers and surrounding communities. This study aims to describe the level of environmental noise at PT. ABC, a glass manufacturing company in Bekasi City, and to formulate environmental management-based noise management strategies. A descriptive research method was employed, involving direct (in situ) measurements using a Sound Level Meter at the upwind monitoring point over a 24-hour period (16–17 April 2026) in accordance with SNI 8427:2017. The gap analysis showed that noise management still needs to be strengthened, particularly in the establishment of environmental objectives, noise source mapping, and evaluation of control effectiveness. Therefore, the proposed noise management strategy refers to an Environmental Management System (EMS) based on the Plan–Do–Check–Act (PDCA) cycle, with priority given to control at the source, supported by control along the propagation path and at the receiver. This approach is expected to improve environmental performance and the operational sustainability of the industry.

Keywords: Environmental noise, glass industry, environmental quality standards, risk control hierarchy, EMS.

I. INTRODUCTION

The working environment plays a critical role in determining worker productivity and occupational health conditions, particularly within the industrial sector (Triansyah et al., 2025). The industrial sector is a vital component of Indonesia's economy due to its ability to produce marketable goods and create employment opportunities. However, industrial activities also expose workers to various occupational hazards that may contribute to occupational diseases and workplace accidents (PAK and KAK) (Irawan et al., 2025). Workplace environmental conditions therefore require careful attention, considering that workers spend approximately one-third of their lives at work (8 out of 24 hours per day), making it essential to ensure occupational health and safety (Raynasti et al., 2023). The growth of industrial activities has generated both positive and negative impacts. On the positive side, industrial development creates employment opportunities, increases national income, maintains economic stability, and contributes to meeting societal needs. Industry plays a major role in the national economy through its capacity to produce goods for commercialisation while absorbing large numbers of workers.

According to data from the Global Burden of Disease (GBD) 2021, occupational noise-induced hearing loss affected approximately 7.84 million people worldwide (Gon et al., 2025). In Indonesia, noise-related occupational health issues remain insufficiently addressed. Data from the Ministry of Health of the Republic of Indonesia (2022) indicate that approximately 30–40% of industrial workers are exposed to noise levels exceeding 85 dB for more than eight hours per day. Noise pollution is a common issue across various industrial sectors, primarily due to the operation of machinery and production equipment that generate high levels of sound (Kholik & Krishna, 2012).

High-intensity noise exposure can result in both temporary and permanent hearing impairment (Silviana et al., 2021). Excessive noise levels may adversely affect human health, causing stress, hearing loss, communication difficulties, reduced concentration, and impairment of the body's balance system (Utami et al., 2020). A study conducted by Soraya involving 120 factory workers in Indonesia found that 52.5% experienced mild to moderate hearing loss, with the majority working in areas where noise levels exceeded 85 dB (Soraya et al., 2025). Uncontrolled noise can also contribute to occupational stress, hinder communication among employees, and increase the risk of workplace accidents due to reduced concentration (Triansyah et al., 2025).

PT ABC is a private company operating in the glass-processing industry. Unlike primary glass manufacturers, the company focuses on processing finished raw glass into various products according to customer specifications, including dimensions and glass types commonly used in building construction. The production process includes cutting, grinding, washing, and further processing into tempered, laminated, and insulated glass products. Many of PT ABC's production activities still rely heavily on manual labour, including activities such as disposing of glass offcuts into cullet boxes, in addition to machine operations. Supporting production facilities include air compressors, electrical substations, water pump installations, and other auxiliary equipment. These manufacturing processes generate considerable noise levels that exceed the normal thresholds established by environmental regulations.

Industrial noise has the potential to affect the comfort, well-being, and health of operators working within the factory environment. Noise monitoring conducted in 2017 recorded levels of 64 dB at the front yard area and 81 dB within the production facility. Subsequent monitoring conducted in 2024 recorded a noise level of 42 dB(A) in the glass production area, which remained below the applicable environmental quality standard. However, measurements conducted during the April 2026 monitoring period revealed that noise levels had exceeded the industrial area noise standard, reaching 71–72 dB(A) during daytime working hours. This finding indicates a significant environmental change that requires further examination and corrective action. Based on these conditions, this article aims to provide an overview of environmental noise levels within a glass manufacturing facility based on field measurement data and to compare these findings with applicable environmental quality standards. Furthermore, the study seeks to conduct a more in-depth analysis of industrial noise management strategies.

Industrial noise management requires not only technical control measures but also a systematic management approach to ensure the effectiveness and sustainability of noise control initiatives. In this context, the Environmental Management System (EMS) based on ISO 14001 provides a structured environmental management framework that enables organisations to identify, control, evaluate, and continuously improve their environmental impacts. Although numerous studies have examined noise levels in industrial environments, most have primarily focused on measuring noise intensity and assessing compliance with environmental standards. Research integrating environmental noise monitoring results with an Environmental Management System (EMS) approach to formulate management strategies based on continuous improvement remains relatively limited, particularly within the glass processing industry. Therefore, this study not only analyses environmental noise levels based on field measurements but also evaluates gaps in existing noise management practices against EMS principles and formulates noise control strategies based on the daytime cycle to support continuous environmental performance improvement.

Unlike previous studies that generally concentrated on noise measurement and compliance assessment, this research integrates environmental noise monitoring results with a gap analysis based on Environmental Management System (EMS) principles to formulate structured and sustainable noise control strategies. This approach provides a practical contribution by linking environmental monitoring data with industrial environmental performance improvement processes, thereby supporting the achievement of sustainable environmental management objectives.

II. LITERATURE REVIEW

Industrial noise is widely recognised as a persistent occupational and environmental hazard, generated primarily by machinery and production processes (Kholik & Krishna, 2012; Wahyudi, 2018). Prolonged exposure has been linked to hearing loss, stress, reduced concentration, and impaired communication, with the Global Burden of Disease study estimating 7.84 million cases of occupational noise-induced hearing loss worldwide (Gon et al., 2025) and national studies reporting hearing impairment in over half of workers exposed to noise above 85 dB (Silviana et al., 2021; Soraya et al., 2025; Utami et al., 2020). Such impacts are especially critical for machine operators, whose performance and safety depend on sustained concentration (Tasyania et al., 2022; Triansyah et al., 2025).

To limit these risks, international bodies (NIOSH, ISO, ILO, WHO) set 85 dB(A) as the permissible 8-hour occupational exposure limit (Kardous et al., 2016), while Indonesian regulation KEP-48/MENLH/XI/1996 sets a 70 dB threshold for industrial areas (Danang et al., 2025). Despite these standards, national data show 30–40% of Indonesian industrial workers remain exposed above safe limits (Depeursinge et al., 2010), indicating a persistent gap between regulation and practice.

Managing this risk effectively requires more than compliance monitoring; it calls for a systematic approach. ISO 14001:2015 provides the Environmental Management System (EMS) framework for identifying, controlling, and continually improving environmental performance (ISO, 2015), structured through the Plan Do Check Act (PDCA) cycle (Peter, 2025). Complementing this, the established hierarchy of noise control, which prioritises source control followed by path and receiver interventions, offers the technical basis for sustainable mitigation (Occupational Safety and Health Administration, 2022).

While prior studies have extensively measured industrial noise levels and assessed regulatory compliance (Kholik & Krishna, 2012; Wardaniyagung, 2023), few have integrated field measurement with EMS-based gap analysis to formulate PDCA-structured management strategies, particularly in the glass-processing industry. This study addresses that gap by combining noise monitoring at PT ABC with an EMS gap analysis to develop a source-prioritised, PDCA-based noise management strategy.

III. METHOD

Noise measurements were conducted at the upwind area (windward) of PT ABC, located in Bekasi City, Indonesia. The monitoring location was situated at coordinates 06°18'12.01" South Latitude and 106°58'49.04" East Longitude. Data collection was carried out on 16–17 April 2026 through continuous 24-hour monitoring, covering all required time periods stipulated under the applicable industrial noise quality standards. Noise intensity measurements were performed directly on-site (in situ) using a Sound Level Meter (SLM). The monitoring procedure followed the requirements of SNI 8427:2017, which serves as the national reference standard for environmental noise measurements in Indonesia. The primary parameter analysed in this study was LAeq (Equivalent Continuous Sound Level), which represents the average acoustic energy level over the measurement period. All measurement results were expressed in A-weighted decibels [dB(A)].

Figure 1. Noise measurement

In accordance with SNI 8427:2017, the monitoring programme was conducted across seven designated time periods as follows:

- Period 1: 06:00–09:00 WIB (measurement conducted at 08:00 WIB)
- Period 2: 09:00–11:00 WIB (measurement conducted at 10:00 WIB)
- Period 3: 14:00–17:00 WIB (measurement conducted at 15:00 WIB)
- Period 4: 17:00–22:00 WIB (measurement conducted at 20:30 WIB)
- Period 5: 22:00–24:00 WIB (measurement conducted at 23:30 WIB)
- Period 6: 00:00–03:00 WIB (measurement conducted at 02:30 WIB)
- Period 7: 03:00–06:00 WIB (measurement conducted at 05:30 WIB)

IV. RESULTS AND DISCUSSION

4.1 Noise Quality Standards

Noise monitoring at PT ABC follows the standards stipulated in the Decree of the Minister of Environment No. 48 of 1996, which establishes the 24-hour noise threshold values for designated areas and activity environments. The applicable noise quality standards are presented in Table 1.

Table 1. Noise Quality Standards

Area Designation	Noise Level
Government and Public Facilities	60 – 65 dB(A)
Offices and Commercial Areas	65 dB(A)
Residential Areas and Settlements	55 dB(A)
Commerce and Services	70 dB(A)
Green Open Spaces	50 dB(A)
Recreational Areas	70 dB(A)
Industrial Areas	70 dB(A)
Specific Areas	
1. Railway Stations	70 dB(A)
2. Seaports	70 dB(A)
3. Airports	70 dB(A)
4. Cultural Heritage Sites	60 dB(A)
Activity Environments	
Places of Worship and Similar Facilities	55 dB(A)
Hospitals and Similar Facilities	55 dB(A)

4.2 Overview of Noise Quality Measurement Results

Noise level measurements were conducted to monitor noise levels at PT ABC, so that any increase in noise resulting from PT ABC's operations could be identified based on the existing baseline conditions. The results of the noise quality measurements are presented in **Table 2, Table 3, and Table 4**.

Table 2. Noise Measurement Results in 2017

No	Sampling Location	Time	Test Result dB(A)
1	Front Yard S 06°18'12.24" E 106^0 58’50.41”	10.00 – 10.10	64
2	Production Area	12.12 – 12.25	81

Environmental noise measurements were conducted at the front yard location. The measurement results presented in Table 2 indicate that the outdoor noise quality parameter at the front yard of PT ABC's industrial activities remained in compliance with the applicable quality standard, with a value of 64 dB(A). Meanwhile, indoor noise measurements indicated a noise quality value of 81 dB(A) in the production area. Based on the Decree of the Minister of Environment No. 48 of 1996 concerning Noise Level Quality Standards, the threshold value established for industrial areas and similar land uses is 70 dB(A). Subsequently, noise quality measurements were conducted to monitor noise levels at PT ABC. The results of the 2024 noise quality measurements are presented in Table 3.

Table 3. Noise Measurement Results for the First Semester of 2024

Sampling Area	Time	Test Result dB(A)
Surrounding Factory Area	11.30	42

The measurement results presented in Table 3 show that the 8-hour noise quality level at the upwind area of PT ABC was 42 dB(A). When compared with the quality standard stipulated in KEP.48/MENLH/XI/1996, namely 70 dB(A), the measured noise level at the monitoring location was still below the applicable standard. Noise intensity measurements were conducted over seven time periods (1 × 24 hours) in the upwind area of PT ABC. Referring to KEP.48/MENLH/XI/1996, the required noise threshold value for industrial land-use areas is 70 dB(A).

Table 4. Noise Measurement Results for the First Semester of 2026

No.	Time Period	Measurement Time	Duration (hours)	Result (dB(A))	Quality Standard (dB(A))	Description
1	L1 — 06:00–09:00 (08:00)	Daytime	3	71	70	EXCEEDS *)
2	L2 — 09:00–11:00 (10:00)	Daytime	2	71	70	EXCEEDS *)
3	L3 — 14:00–17:00 (15:00)	Daytime	3	72	70	EXCEEDS *)
4	L4 — 17:00–22:00 (20:30)	Daytime	5	70	70	Complies
5	L5 — 22:00–24:00 (23:30)	Night-time	2	69	70	Complies
6	L6 — 00:00–03:00 (02:30)	Night-time	3	70	70	Complies
7	L7 — 03:00–06:00 (05:30)	Night-time	3	70	70	Complies
*) Results exceed the environmental quality standard (KEP.48/MENLH/XI/1996). Measurement method: SNI 8427:2017.						

The complete measurement results are presented in Table 5. Based on these data, noise intensity during periods L1 to L3 showed values exceeding 70 dB(A) and were therefore categorised as exceeding the environmental quality standard at the monitoring location. Meanwhile, periods L4 to L7, which occurred during the night-time period, recorded values that complied with the applicable quality standard.

During the daytime period, the highest noise level was recorded during Period L3 (14:00–17:00 WIB) at 72 dB(A), exceeding the quality standard by 2 dB(A). This condition is closely related to production activities operating at full capacity during daytime working hours, including glass cutting, grinding, and washing processes. Periods L1 and L2 each recorded values of 71 dB(A), also exceeding the quality standard, indicating that noise levels during morning and daytime operational hours consistently remained above the permissible threshold.

In contrast, during the night-time period, noise levels tended to decrease and remained at or below the applicable quality standard. Period L5 (22:00–24:00 WIB) recorded the lowest value at 69 dB(A), indicating that reduced production activities and vehicle traffic during night-time hours contributed to lower noise intensity in the industrial surroundings. Periods L4, L6, and L7 each recorded values exactly at the quality standard threshold of 70 dB(A) and were therefore categorised as complying with the applicable requirements, although they were at the permissible limit.

Overall, the measurement results indicate that noise levels in the upwind area of PT ABC during the daytime period require particular attention, given that three out of seven measurement periods exceeded the established noise threshold value.

The monitoring results indicate that part of PT ABC's operational period exceeded the noise quality standard for industrial areas. This finding suggests that noise management cannot be carried out solely through monitoring activities but requires an environmental management approach capable of ensuring that control measures are implemented in a planned, documented, and sustainable manner. In this context, the Environmental Management System (EMS) can be utilised as an evaluation framework to identify management gaps and formulate more effective improvement strategies.

4.3 Noise Management Strategy Based on Environmental Management Principles

Noise management is not only intended to fulfil environmental quality standards, but also to ensure that environmental risks and health risks arising from noise exposure can be controlled systematically and sustainably. In practice, the success of noise control is not determined solely by the application of control technologies, but also by the effectiveness of the management system that supports the processes of planning, implementation, evaluation, and improvement. Therefore, the ISO 14001-based Environmental Management System (EMS) approach can be used as a framework to evaluate noise management at PT ABC and to identify areas that still require improvement through a continual improvement approach. Based on the results of observations and evaluations of the noise management practices that have been implemented, a gap analysis was conducted between the actual condition of PT ABC and the principles of the EMS. This analysis aims to identify aspects that have fulfilled the principles of environmental management, as well as aspects that still require strengthening as the basis for developing a more effective noise control strategy.

Table 5. Gap Analysis of Noise Management Based on Environmental Management System (EMS) Principles at PT ABC

EMS Element	Current Condition at PT ABC	Expected Condition	Gap Level
Environmental Aspect Identification	Noise has been identified as an environmental aspect.	Environmental aspect identification is conducted periodically and documented.	Low
Noise Monitoring	Noise measurements are conducted periodically.	Monitoring is conducted systematically and serves as a basis for decision-making.	Low
Environmental Objective Setting	No measurable noise reduction targets have been established.	Environmental targets and performance indicators are established.	High
Noise Source Mapping	Comprehensive noise mapping has not yet been conducted.	Noise mapping is conducted to identify noise hotspots.	High
Noise Source Control	Control measures are limited to operational controls and personal protective equipment (PPE).	Priority is given to controlling noise at the source.	Moderate
Evaluation of Control Effectiveness	No quantitative evaluation has been conducted.	Routine evaluations of programme effectiveness are conducted.	High
Environmental Audit	No specific audit has been conducted for the noise aspect.	Audits are conducted periodically.	Moderate
Continual Improvement	No long-term noise reduction programme has been established.	A continual improvement programme is implemented.	High

At the implementation stage (Do) control measures should be implemented based on the principles of the hierarchy of risk control by prioritising control at the noise source. This approach is considered the most effective method because it is capable of reducing noise levels directly at the point of origin (Occupational Safety and Health Administration, 2022). At PT ABC, these efforts can be implemented through periodic preventive maintenance of machinery, modification of equipment that generates high levels of noise, and the application of more efficient work procedures to minimise noise generated from production processes and cullet handling activities. In addition to source control, control of the sound propagation pathway can be implemented through the installation of noise barriers, machine enclosures, the use of sound-absorbing materials in specific areas, and optimisation of the production facility layout to reduce the spread of noise to work areas and the surrounding environment. The use of vegetation as a buffer zone may also be considered as a supporting measure to reduce the propagation of noise beyond the industrial area. Control at the receiver is implemented as a final alternative when source control and pathway control are unable to reduce noise levels optimally. This may be achieved through the use of personal protective equipment (PPE), such as earplugs and earmuffs, for workers who are potentially exposed to high noise levels. Although PPE does not directly reduce noise levels within the workplace environment, its use remains necessary as a protective measure against health risks to workers (ISO, 2015). The monitoring results should subsequently be compared with the applicable environmental quality standards to assess the effectiveness of the control measures that have been implemented. In addition, internal environmental audits may also be conducted to ensure that all noise management procedures have been carried out in accordance with the established requirements.

Subsequently, the improvement stage (Act) is carried out by refining the control strategy based on evaluation results and field findings. If there are still areas that exceed the applicable quality standards, the company needs to make adjustments to the control methods being applied, whether through technological improvements, modifications to operational procedures, or the strengthening of internal policies related to noise management. In addition to technical approaches, the success of noise management is also strongly influenced by institutional and behavioural aspects. Therefore, it is necessary to integrate the noise control strategy into the company's management system through the development of standard operating procedures (SOPs), worker training and awareness enhancement programmes, and the strengthening of management commitment to environmental performance. The involvement of all stakeholders, both internal and external, is a key factor in achieving effective and sustainable noise management. Through the implementation of an integrated environmental management-based noise management strategy, PT ABC will not only be able to comply with the standards established by regulations, but also improve the quality of the working environment, protect workers' health, and support the long-term sustainability of industrial operations.

Figure 2. Noise outreach/awareness campaign

CONCLUSION

The results of environmental noise monitoring at the upwind monitoring point of PT ABC, Bekasi City, conducted continuously over a 24-hour period across seven measurement intervals, indicated that three daytime monitoring periods, namely L1, L2, and L3, recorded LAeq values ranging from 71 to 72 dB(A). These values exceeded the environmental quality standard for industrial areas, which is set at 70 dB(A) under KEP.48/MENLH/XI/1996 This increase was likely influenced by the addition of production machinery, glass-processing activities, cullet handling operations, and the increasing intensity of freight transportation activities within the area.

The implementation of a noise control strategy should refer to the principles of the Environmental Management System (EMS) through the Plan–Do–Check–Act (PDCA) cycle, so that control efforts are not only technical in nature but are also sustainable and adaptive to changes in operational conditions. Noise management strategies should focus primarily on control at the source level, supported by control along the sound propagation pathway and at the receiver level, in accordance with the principles of the hierarchy of risk control. The findings of this study indicate that the integration of noise monitoring results with an Environmental Management System (EMS) approach can serve as a basis for developing a more structured, adaptive, and sustainable noise management strategy within the glass processing industry.

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