**NUSRA: Jurnal Penelitian dan Ilmu Pendidikan**
Volume 7, Issue 2, May 2026
DOI: https://doi.org/10.55681/nusra.v7i2.6222
Homepage: ejournal.nusantaraglobal.ac.id/index.php/nusra

p-ISSN: 2715-114X
e-ISSN: 2723-4649
pp. 640-647

# EVALUATION OF INDOOR HEALTH AND COMFORT (IHC) IN CLASSROOMS: QUANTITATIVE ANALYSIS OF LIGHTING AND NOISE DURING THE AFTERNOON TRANSITION PERIOD

Chillie Aurora Meydiano[1*], Agil Fitri Handayani[2], Clara Devina Rizki Alfreda[3], Clarissya Ayuningtyas[4], Dafa Sashi Ramdhani[5], Tee Tze Kiong[6]
[1-4)]Department of Building Engineering Education, Universitas Negeri Malang, Malang, Indonesia,
[5)]Faculty of Technical and Vocational Education, Universiti Tun Hussein Onn Malaysia, Batu Pahat, Johor, Malaysia
*Corresponding author email: chillie.aurora.2405216@students.um.ac.id*

**Article History**

**Received: 27 April 2026**
**Revised: 16 May 2026**
**Published: 28 May 2026**

## ABSTRACT

*This study aims to evaluate Indoor Health and Comfort (IHC) in a classroom environment through a quantitative analysis of lighting (visual) and noise (auditory) parameters during the afternoon transition period (12:00–15:00 local time). A descriptive quantitative approach was employed using direct field measurements with a lux meter and a sound level meter in a 9 × 7 meter classroom. Measurements were conducted at 48 grid points with a spacing of 1 meter and at a height of approximately 0.8 meters, representing the students' working plane. The collected data were analyzed by comparing them with established standards, namely SNI 03-6575-2001 for lighting (≥250 Lux) and the Ministerial Decree on Environment No. 48 of 1996 for noise (≤55 dB). The results indicate that the average lighting level of 214.77 Lux is below the required standard, with approximately 62% of the measurement points classified as non-compliant. In contrast, the average noise level reaches 57.31 dB, exceeding the permissible threshold, with 72% of the points surpassing the limit. The simultaneous occurrence of insufficient lighting and excessive noise creates a double burden effect that may negatively influence students' visual comfort, concentration, and overall learning performance. Furthermore, temporal observations reveal a consistent decline in lighting intensity from approximately 242 Lux at 12:00 to 185 Lux at 15:00, confirming the afternoon transition period as a critical window for classroom IHC management. Therefore, this study recommends integrated improvement strategies, including optimizing artificial lighting systems, enhancing daylight utilization, and implementing acoustic control measures to improve classroom environmental quality.*

***Keywords:*** *indoor health and comfort, Classroom, learning comfort*



***How to cite:*** Meydiano, C.A., Handayani, A.F., Alfreda, C.D.R., Ayuningtyas, C., Ramdhani, C.S. & Kiong, T.T. (2026). EVALUATION OF INDOOR HEALTH AND COMFORT (IHC) IN CLASSROOMS: QUANTITATIVE ANALYSIS OF LIGHTING AND NOISE DURING THE AFTERNOON TRANSITION PERIOD. *NUSRA: Jurnal Penelitian Dan Ilmu Pendidikan*, 7(2), 640–647. https://doi.org/10.55681/nusra.v7i2.6222

## BACKGROUND

Educational facilities play a pivotal role in supporting effective and high-quality learning processes. The physical state of the classroom directly influences students' capacity to assimilate instructional content and sustain concentration throughout the school day. The concept of Indoor Environmental Quality (IEQ), operationally referred to as Indoor Health and Comfort (IHC) within educational settings, offers a pertinent framework for evaluating the indoor environment, encompassing visual comfort, auditory comfort, thermal comfort, and air quality (Toyinbo, 2023; Miri et al., 2025).

Visual comfort in classrooms is largely determined by the adequacy of lighting relative to instructional activities. Insufficient illumination can cause eye strain, reduced reading efficiency, and progressive cognitive fatigue among students (Zhou & Pan, 2023). The Indonesian lighting standard SNI 03-6575-2001 mandates a minimum illumination level of 250 lux for active classroom environments (Badan Standardisasi Nasional, 2001).

In addition to lighting, auditory comfort constitutes another essential factor shaping a conducive learning atmosphere. Excessive noise can interrupt verbal communication between teachers and students, degrade concentration, and elevate stress due to unwanted sound exposure. Indonesia's noise quality standard, Ministerial Decree on Environment No. 48 (1996), sets a maximum of 55 dB for educational zones (Kementerian Lingkungan Hidup, 1996).

International research consistently demonstrates a significant association between classroom environmental quality and academic performance. Al Jumaili & Sabbagh (2024) reported that inadequate lighting in classrooms correlated with up to a 20% decline in academic achievement relative to optimally lit environments. Similarly, Miri et al. (2025) found that noise exposure exceeding 55 dB during instructional hours substantially impaired students' auditory comprehension abilities.

Moreover, the concurrent interaction of suboptimal lighting and excessive noise, described as the double burden or dual sensory stressor phenomenon, imposes more complex psychological strain than either factor alone. Journal of Building Engineering (2023) reported that simultaneous exposure to both stressors can accelerate cognitive fatigue up to three times faster compared to single-factor exposure, underscoring the urgent need for integrated IHC evaluation.

Previous studies have predominantly evaluated environmental parameters in isolation and during morning-to-midday hours. However, the afternoon transition period (12:00 - 15:00 local time) exhibits distinct characteristics: declining solar elevation angles progressively reduce natural light penetration through windows, while increasing school activity during that timeframe potentially amplifies ambient noise levels (Zhou & Pan, 2023).

Identifying this research gap, the novelty of this study lies in its integrated simultaneous evaluation of lighting and noise within a unified IHC framework, specifically focused on the afternoon transition period as a critical yet understudied window of school activity. The research objectives are: (1) to measure and evaluate existing lighting and noise conditions in the classroom; (2) to compare measurements against applicable standards; (3) to identify distribution patterns and temporal variations in both parameters; and (4) to formulate evidence-based, structured improvement recommendations.

## RESEARCH METHODS

This study employs a descriptive quantitative research design with an evaluative approach, aimed at assessing the degree of compliance with Indoor Health and Comfort (IHC) criteria in a classroom setting based on lighting and noise parameters. The quantitative method was selected for its capacity to provide objective representations of physical environmental conditions through direct measurement, yielding numerically comparable results against established regulatory standards (Toyinbo, 2023). The overall research design is cross-sectional observational in nature, wherein all measurements were conducted within a defined time window to capture the actual environmental condition of the classroom during the afternoon transition period.

The research was conducted in an active classroom at a secondary educational facility in Malang City, East Java, Indonesia. The selected classroom measured 9 × 7 meters with a ceiling height of 3.5 meters, yielding a total interior volume of 220.5 m³. Site selection was carried out through purposive sampling based on three criteria: active utilization during midday learning hours, limited natural lighting aperture restricted to one side of the room, and exposure to variable ambient noise from school activities and the surrounding environment. The classroom features two window openings on the north-facing wall with a combined glazed area of approximately 6 m², and is equipped with six ceiling-mounted fluorescent luminaires as the sole artificial lighting source.

Data were collected through systematic direct field observation using a digital lux meter for lighting intensity and a sound level meter for noise levels. Both instruments were calibrated prior to use to ensure measurement validity and accuracy (Miri et al., 2025). Measurement points were distributed across the classroom floor using a 1-meter interval grid method, generating 48 measurement points in a 6-column × 8-row configuration, all at a uniform height of 0.8 meters above floor level corresponding to the occupant working plane as prescribed by SNI 03-6575-2001 (Badan Standardisasi Nasional, 2001). All measurements were conducted within the 12:00–15:00 local time window. For lighting, each point was recorded six times at 20-minute intervals with readings taken after the display stabilized for a minimum of 5 seconds. For noise, the sound level meter was operated in fast-response mode using the A-weighting scale (dBA), with each reading recorded following stabilization of no less than 30 seconds per point.

Measurement data were analyzed through a descriptive quantitative approach in four sequential stages: calculation of mean, minimum, and maximum values; frequency distribution analysis to determine the proportion of compliant and non-compliant measurement points; comparative analysis against applicable standards, specifically SNI 03-6575-2001 prescribing a minimum illuminance of 250 Lux and Ministerial Decree No. 48 of 1996 stipulating a maximum noise level of 55 dB; and temporal variation analysis across the six measurement intervals to identify parameter fluctuation trends throughout the afternoon transition period (Miri et al., 2025).

## RESULT AND DISCUSSION

### 1. *Measurement Results*

Measurement results for lighting and noise parameters during the afternoon transition period are summarized in Table 1. The data reveals a comprehensive picture of IHC non-compliance across both environmental dimensions evaluated.

**Table 1. Summary of Classroom IHC Measurement Data**

| Parameter | Min Value | Average | Max Value | Standard | Status |
|---|---|---|---|---|---|
| Lighting (Lux) | 10.3 | 214.77 | 315.4 | ≥ 250 | Non-compliant |
| Noise (dB) | 13.2 | 57.31 | 82.8 | ≤ 55 | Non-compliant |

Table 1 demonstrates that the average lighting value of 214.77 Lux falls below the minimum standard of 250 Lux, with a highly significant variation between minimum (10.3 Lux) and maximum (315.4 Lux), indicating extremely uneven light distribution. Meanwhile, the average noise level of 57.31 dB exceeds the 55 dB threshold, with a maximum of 82.8 dB suggesting extreme sound fluctuations at certain intervals.

### 2. *Lighting Analysis*

Figure 1 presents the distribution of lighting intensity by minimum, mean, and maximum values compared to the SNI standard. It is evident that the average value (214.77 Lux) falls below the 250 Lux standard line, despite certain measurement points achieving above-standard values.

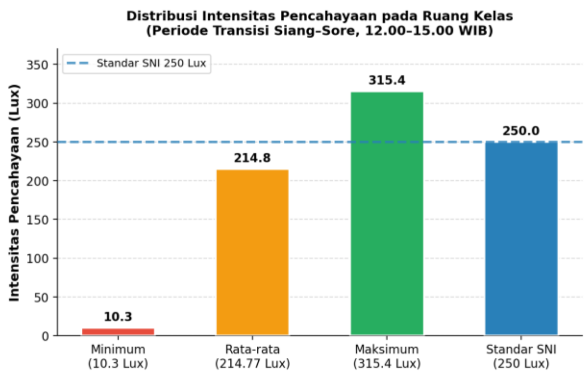


**Figure 1. Lighting Intensity Distribution in the Classroom**

This condition is attributable to several technical factors. Natural light enters the room only through the north-facing windows, creating a steep light gradient toward the interior. Areas more than 3 meters from the windows generally receive intensity levels well below 150 Lux during the late afternoon as the sun's elevation angle decreases progressively. The existing artificial lighting system (6 fluorescent units) cannot adequately compensate in a uniform manner. These findings are consistent with Zhou & Pan (2023), who established that lighting uniformity is equally important as mean illuminance. In this study, the uniformity ratio stands at only 0.048 (10.3/214.77), far below the recommended 0.6.

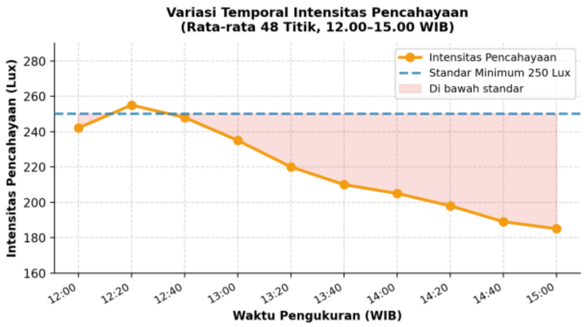


**Figure 2. Temporal Variation of Lighting Intensity (12:00–15:00)**

Figure 2 illustrates the temporal variation in average lighting intensity across all 48 points. A consistent downward trend is observed, declining from approximately 242 Lux at 12:00 to 185 Lux at 15:00. This pattern confirms that the afternoon transition period is a critical window requiring particular attention in classroom lighting system design.

### 3. *Noise Analysis*

Figure 3 presents the distribution of noise levels by minimum, mean, and maximum values compared to the Ministerial Decree threshold of 55 dB. The average value (57.31 dB) visibly exceeds the regulatory line, with the maximum value substantially above the permissible limit.

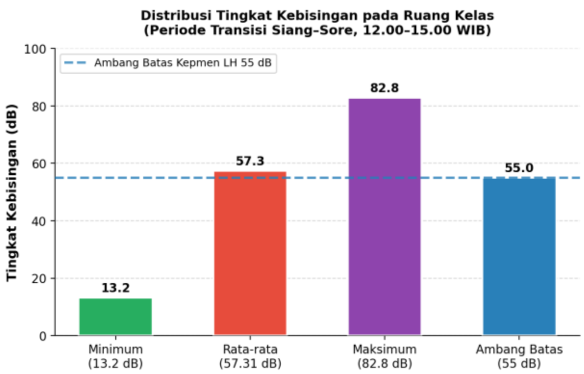


**Figure 3. Noise Level Distribution in the Classroom**

Elevated noise levels are attributable to multiple factors. Externally, noise infiltrates through window apertures that lack acoustic treatment, and school activity during 12:00 - 15:00 is inherently high corridor movement, vehicular activity, and outdoor recreational activities collectively raise ambient noise. Internally, hard surface materials (ceramic floor tiles, plastered masonry walls, gypsum board ceilings) cause significant reverberation. The 2.31 dB excess above the regulatory threshold represents approximately 41% greater sound intensity than permissible, demonstrably affecting auditory communication clarity and student comprehension (Journal of Building Engineering, 2023).

### 4. *IHC Evaluation*

Figure 4 provides a direct comparison between measured values and standards for both IHC parameters. Both conditions simultaneously indicate that the classroom fails to meet the required IHC criteria across the two most critical sensory dimensions for learning quality.

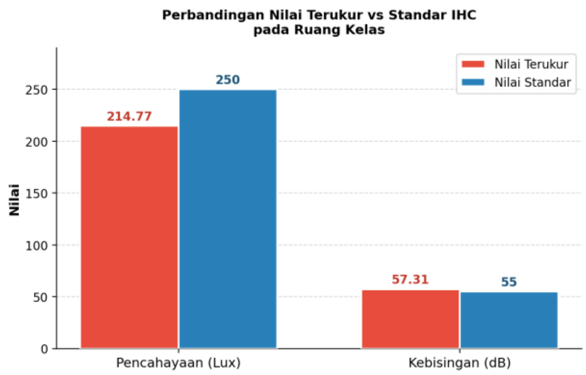


**Figure 4. Comparison of Measured Values vs. IHC Standards**

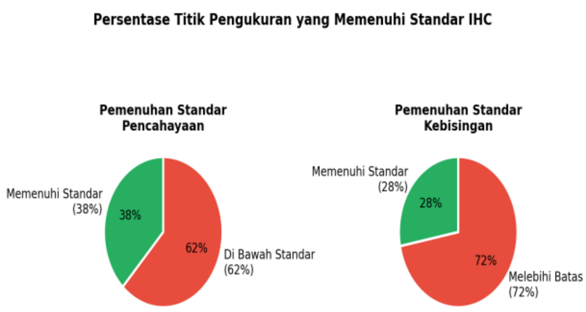


**Figure 5. Percentage of Measurement Points Meeting IHC Standards**

Figure 5 visually confirms that approximately 62% of lighting measurement points fail to meet SNI standards, while approximately 72% of noise measurement points exceed the permissible limit. This confirms that the IHC deficiency is a systemic condition. The *double burden* phenomenon carries implications more serious than single-factor disturbances: simultaneous exposure to inadequate lighting and excessive noise produces synergistic negative effects requiring students to expend additional cognitive resources to compensate for both stressors concurrently (Journal of Building Engineering, 2023). Long-term health implications visual disorders from substandard lighting and hearing impairment or elevated blood pressure from chronic noise exposure further necessitate urgent and comprehensive intervention (MDPI Buildings, 2024).

### 5. *Improvement Recommendations*

Regarding lighting: (1) install additional high-efficiency LED luminaires (minimum 100 lm/W) with at least 4 additional units strategically distributed to address dark zones; (2) retrofit existing fixtures with optical reflectors to improve distribution efficiency; (3) implement daylight-linked lighting control systems to automatically compensate for declining natural light; and (4) explore feasibility of additional window apertures or skylights to enhance natural light penetration.

Regarding acoustics: (1) install sound-absorbing panels on rear and side walls using rockwool or high-density acoustic foam; (2) introduce soft floor coverings to dampen footfall noise; (3) upgrade single-glazed windows to double-glazed units or add secondary glazing; (4) install door seals and acoustic sweeps to minimize sound leakage; and (5) incorporate green plantings near the classroom exterior as a natural acoustic buffer. Complementary behavioral strategies should include scheduling high-noise activities away from intensive learning periods and establishing periodic IHC monitoring protocols.

## CONCLUSION

This study concludes that the Indoor Health and Comfort (IHC) conditions in the evaluated classroom fail to meet applicable standards across both assessed parameters. The average lighting level of 214.77 Lux falls below the SNI 03-6575-2001 minimum of 250 Lux, with approximately 62% of measurement points non-compliant and a uniformity ratio of only 0.048—far below the recommended 0.6. On the acoustic dimension, the average noise level of 57.31 dB exceeds the Ministerial Decree No. 48/1996 threshold of 55 dB, with approximately 72% of measurement points surpassing the regulatory limit and a maximum of 82.8 dB indicating extreme fluctuations. Temporal analysis confirms a consistent worsening of lighting conditions from 12:00 to 15:00. The simultaneous non-compliance of both parameters creates a double burden phenomenon with synergistically negative effects on student learning comfort and cognitive performance. This study recommends: optimization of artificial lighting systems with energy-efficient LED fixtures and daylight-responsive controls; acoustic treatment with sound-absorbing materials; external noise insulation through upgraded window glazing and acoustic door seals; and implementation of a periodic environmental monitoring framework to ensure sustained IHC quality improvement.

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