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Impact of railway noise on student concentration in classroom learning: An environmental and educational perspective

Tesar Mahardika[1], Sugeng Widodo[1,*]
[1] *Geography Education Study Program, Faculty of Teacher Training and Education, Universitas Lampung, Bandar Lampung, Lampung 35145, Indonesia.*
*Correspondence: sugengwidodo@fkip.unila.ac.id

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ABSTRACT
Background: Environmental noise pollution, particularly from railway activities, poses a significant challenge to student concentration and learning effectiveness. This study investigates the correlation between railway noise levels and student concentration in classroom learning within an environmental education framework. **Method:** The method used in this study is descriptive quantitative. The population in this study were all fifth-grade students of State Elementary School 1 Rajabasa Raya totaling 98 students. The sample of this study was 78 respondents. **Findings:** The results of the study regarding the intensity of noise measured have exceeded the threshold value (nab). While the results of the product moment correlation analysis method, there is a relationship between train noise and student learning concentration at State Elementary School 1 Rajabasa Raya with a value of p = 0.000 (p <0.005). **Conclusion:** Persistent railway noise has a measurable adverse effect on student learning concentration, emphasizing the need for environmental education-based mitigation strategies. **Novelty/Originality of this article:** This study contributes to the field of environmental education by integrating noise pollution analysis with student learning outcomes. It highlights the necessity of soundproofing measures, school infrastructure adjustments, and adaptive learning strategies to minimize the impact of environmental noise on education.

KEYWORDS: railway noise; learning concentration; environmental health; geography; noise mapping**.**

1. Introduction

The increasingly dense transportation activities in urban areas certainly produce quite high noise with a long frequency. One example of a transportation activity that produces quite high noise is train activity. The noise produced will affect the surrounding environment, one of which is a school located around a railroad crossing. Schools as a place for teaching and learning processes should be in a calm and conducive environment, to create a maximum learning process. Learning activities in schools are not only influenced by internal factors, but also by external factors (Kurniawan et al., 2021). One of them is the condition of the surrounding environment. An uncomfortable environment results in decreased effectiveness in an activity, process, or result.

According to the opinion put forward by the World Health Organization (WHO), noise can be interpreted as any sound that is not needed and has a negative effect on the quality of life, health and well-being (World Health Organization, 1999). In addition, noise can also

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be interpreted as unwanted sound from efforts or activities at a certain level and time that can cause health problems and environmental comfort (Ministry of Environment and Forestry, 1996). In Indonesia, the pervasive presence of train noise near educational institutions has raised concerns regarding its impact on students' concentration and overall cognitive development. A study conducted by Prabaningrum (2017) at public elementary schools adjacent to railway crossings in Tebet, South Jakarta, revealed that the equivalent noise level reached 66.84 dBA. It is surpassing the standard threshold of 55 dBA set by the Decree of the Minister of Environment of the Republic of Indonesia No. 48 of 1996 on Noise Level Standards (Ministry of Environment and Forestry, 1996). Although the study found no statistically significant relationship between noise levels and student concentration, it highlighted that daily exposure to noise levels exceeding 55 dBA could make students more susceptible to concentration disturbances.

Transportation noise is increasingly recognized as a major environmental pollutant with wide-ranging health and quality-of-life impacts. WHO notes that road, rail and air traffic are important sources of community noise and in Europe traffic noise was estimated to cost over one million healthy life years in 2011. Studies show that excessive noise causes annoyance and sleep disturbance and raises the risks of hypertension, heart disease, hearing loss and cognitive impairment (World Health Organization, 2011). For example, the European Environment Agency estimates that transport noise leads to about 39,800 new cases of ischemic heart disease and over 10,000 premature deaths per year in the EU (European Environment Agency, 2020). Taken together, this evidence underscores that persistent train noise near a school is not just a nuisance but a significant public health hazard that can degrade students' learning conditions and well-being.

The World Health Organization has formally classified noise as an environmental health hazard and issued guidelines to protect people from chronic exposure. In its 2018 European environmental noise guidelines, WHO recommends that long-term average railway noise (Lden) not exceed 54 dB, since levels above this are linked to adverse health outcomes. These guidelines cover noise from all major transport sources and emphasize that policy action is needed to limit community exposure (World Health Organization, 2018b). In practice, many countries set similar limits: for example, Indonesian regulations prescribe a maximum of 55 dBA for schools (the same standard cited earlier). When measured train noise levels exceed these thresholds, mitigation measures – such as sound-insulating classrooms or altering school layouts – become critical to ensure a healthy learning environment (World Health Organization, 2018b).

Railway operations also contribute to air pollution, compounding the environmental risk to schools. Diesel locomotives emit fine particulate matter (PM2.5) and nitrogen oxides into the atmosphere. In fact, WHO's International Agency for Research on Cancer has classified diesel engine exhaust – including emissions from trains – as carcinogenic to humans (International Agency for Research on Cancer, 2012). Moreover, ambient air pollution is known to harm children's health and development: WHO reports that polluted air impairs neurodevelopment and cognitive ability and increases risks of asthma and cardiovascular disease in youth (World Health Organization, 2018a). To protect students, WHO specifically advises that schools be sited away from major transport and pollution sources (World Health Organization, 2018a). In sum, schools adjacent to diesel-powered rail lines face a dual burden of elevated noise and air pollution, both of which can undermine student concentration and health in the classroom.

Further research by Faradiba (2017) at SMA Negeri 37 Jakarta, a school situated adjacent to a railway crossing, measured an average noise level of 70.50 dB across five measurement points. This figure significantly exceeds the maximum permissible noise level of 55 dB for school environments, as stipulated by environmental regulations. The study emphasized the necessity for noise control measures within the school to mitigate potential negative impacts on students. International studies corroborate these findings. Research conducted by the Barcelona Institute for Global Health (2022) indicated that traffic noise at schools adversely affects the development of working memory and attention in primary-school students. The study found that a 5 dB increase in outdoor noise levels resulted in working memory development that was 11.4% slower than average and attention capacity development that was 4.8% slower than average.

Collectively, these studies underscore the pressing need for effective noise mitigation strategies in schools located near railway lines in Indonesia. Implementing environmental engineering solutions, such as soundproofing classrooms and redesigning school layouts to minimize noise exposure, is essential to safeguard students' cognitive development and academic performance. Noise zones are noise classifications based on their designation. Regulation of the Minister of Health of the Republic of Indonesia number 718/MENKES/PER/XI/1987 states the division of noise levels into four zones according to Table 1, namely:

Table 1. Noise zone

Zone	Allocation	Noise Level	
		Maximum recommended	Maximum allowed
A	Health/social facilities, research sites	35	45
B	Housing, education, recreation	45	55
C	Offices, trade/markets	50	60
D	Industry, factories, train stations, bus terminals	60	70

(Mirjaz et al., 2024)

The school is located in zone B. If the noise level in the school exceeds the limit, the environmental conditions are no longer conducive so that it can have an impact on learning comfort. Research indicates that exposure to transportation noise adversely affects children's cognitive functions, including attention and memory. A study by van Kempen et al. (2010) found that children in noisier schools made more errors in complex attention tasks, suggesting that noise impairs cognitive performance. Similarly, Foraster et al. (2022) reported that higher road traffic noise levels at schools were associated with slower development of working memory and attention in students. These findings underscore the need for effective noise mitigation strategies in Indonesian schools near railway lines to protect students' learning outcomes.

Noise affects the concentration of students (Caviola et al., 2021). When noise occurs in the classroom, students will reflexively react to the noise and will try to find where the sound is coming from. State Elementary School 1 Rajabasa Raya is one of the educational facilities located close to the railroad tracks. This study aims to measure noise in the environment of State Elementary School 1 Rajabasa Raya and to see the relationship between train noise and student learning concentration at State Elementary School 1 Rajabasa Raya.

2. Methods

2.1 Tools and materials

The instruments and materials used in this study consisted of a digital sound level meter (SLM) used to measure the noise intensity generated by passing trains around State Elementary School 1 Rajabasa Raya. The instrument complied with IEC 61672 Class 1 standards and was calibrated before use. A structured questionnaire was designed to evaluate students' perceived disturbance and concentration levels during classroom activities. The questionnaire employed Likert-scale items to measure the level of distraction caused by train noise. SPSS version 20.0 was used to perform the Pearson Product-Moment Correlation analysis to examine the relationship between railway noise and students' concentration levels. The research site was located in State Elementary School 1 Rajabasa Raya, Bandar Lampung, where the fifth-grade classrooms are located closest (approximately 25–35 meters) to the railway line connecting Tanjungkarang–Palembang.

2.2 Procedure

This study applied a descriptive quantitative research design. The population consisted of 579 students across grades I–VI, while the sample of 98 fifth-grade students was selected using purposive sampling, considering that this group was most directly affected by railway noise exposure. Noise measurements were carried out using the SLM at three classroom points (V-A, V-B, and V-C) during regular teaching hours to capture realistic conditions. The instrument was positioned 1.2 meters above the floor and at least 1 meter from the wall, and measurements were recorded in three sessions (morning, mid-day, and afternoon) to account for variations in train activity.

The data collected were processed to calculate the Equivalent Continuous Noise Level (Leq), which represents the continuous equivalent value of fluctuating noise intensity. The Leq results were then compared with the Noise Threshold Value (NAB) for educational zones (55 dB) as stipulated in Indonesian Ministry of Environment Regulation No. 48/1996*.* Students' questionnaire responses were quantified into numerical scores and statistically correlated with measured noise levels using Pearson's Product-Moment Correlation to determine the relationship strength between noise and concentration. Additionally, classroom spatial data (distance to railway, orientation, and structural layout) were recorded using GPS to provide a geographical interpretation of the results. This spatial aspect allowed the study to analyze not only the statistical but also the environmental and locational dimensions of railway noise exposure.

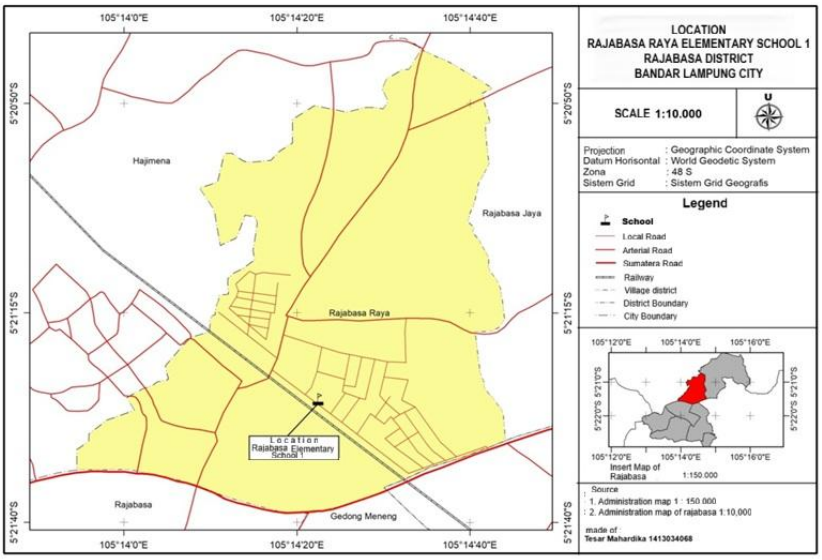

Fig. 1. Research location

3. Results and Discussion

3.1 Noise level

Noise level measurements were carried out in class V of State Elementary School 1 Rajabasa Raya, with measurements being taken at three points, namely classes V-A, V-B, and V-C. Noise level measurements were carried out when the train passed. Based on the noise values obtained from three measurement point locations in class V of State Elementary School 1 Rajabasa Raya, when the train passed, the noise value exceeded the threshold value (nab). The results of this measurement also showed a strong noise scale level, referring to the noise scale intensity guidelines which was compared to the average noise intensity. So, it can be concluded that State Elementary School 1 Rajabasa Raya has been exposed to noise.

Table 2. Classroom noise measurement results

No	Room of class	Measurement score			
		Before the train passes		When the train passes	
		Noise value	(NAB)	Noise value	(NAB)
1	V-A	54.05	55	67.36	55
2	V-B	54.27	55	68.03	55
3	V-C	52.14	55	65.15	55

The noise level in schools should not exceed 55 dB because it can affect the learning process. The effects of noise exposure on students who are studying result in a decrease in student learning performance. Noise can cause physiological and psychological disorders. This will reduce the level of concentration of students in following the learning process in class. The measured noise levels at State Elementary School 1 Rajabasa Raya clearly indicate that railway operations have produced an acoustic environment that exceeds the recommended limits for educational institutions. As shown in Table 2, noise levels during train passes reached between 65–68 dB, surpassing the Noise Threshold Value (NAB) of 55 dB. According to the classification in Table 3, these values fall within the "strong" category, comparable to noise in busy office environments or open streets. The persistence of such noise conditions during learning hours suggests that the school operates within a chronically disturbed soundscape.

Table 3. Noise intensity scale

Noise scale	dB	Noise source
Deafening	100-120	Thunder, cannons, steam engines
Very load	80-100	Noisy streets, very noisy businesses, police whistles
Strong	60-80	Noisy offices, streets in general, radio, businesses
Moderate	40-60	Noisy homes, offices in general, loud conservations, radio
Quiet	20-60	Quiet homes, individual offices, auditoriums, conservations
Very quiet	0-20	Leaf noise, whispered conservations

From an environmental perspective, this situation reflects continuous acoustic pollution. Chronic noise exposure, even at levels between 60–70 dB, has been linked to physiological and psychological stress reactions in children (Stansfeld & Matheson, 2003; van Kempen et al., 2010). Long-term exposure triggers hormonal responses such as elevated cortisol secretion and increased heart rate, which can influence mood, focus, and learning capacity (Clark et al., 2018; Foraster et al., 2022). Moreover, environmental noise represents a form of non-auditory pollution that reduces overall environmental quality in schools, where concentration and verbal communication are critical.

Geographically, the location of State Elementary School 1 Rajabasa Raya plays a decisive role in shaping this exposure pattern. The school lies approximately 25–35 meters from the railway track—within what can be considered a primary noise buffer zone. Studies using GIS-based spatial modeling confirm that noise exposure tends to form elongated high-intensity belts along transport corridors (Zafar et al., 2023; Gharehchahi et al., 2024). Classrooms positioned with direct line-of-sight to the track (V-A and V-B) recorded higher Leq values than more shielded spaces, illustrating a clear spatial gradient. This finding suggests that land-use planning and building orientation should be integral components of school environmental design, especially in densely built railway-adjacent areas.

From a policy and planning standpoint, the results highlight the need for systematic noise mapping around educational facilities. The European Environment Agency (2020) recommends strategic noise maps and action plans for transport corridors exceeding specific traffic thresholds. Applying similar principles in Indonesian urban settings could help local governments prioritize mitigation at critical exposure zones. Simple GIS buffers (0–100 m, 100–300 m, >300 m) combined with measured Leq data could be used to categorize schools according to risk and to identify where green barriers, acoustic walls, or building retrofits are most urgently required.

Furthermore, the environmental impact is not limited to acoustic exposure alone. Diesel-powered train operations generate dual environmental burdens—noise and air pollutants such as particulate matter (PM2.5) and nitrogen oxides (NOx). Both exposures are known to have interactive effects on children's neurocognitive development (Foraster et al., 2022). Therefore, mitigation strategies for State Elementary School 1 Rajabasa Raya should adopt an integrated environmental management approach, combining acoustic interventions such as double-glazed windows, sound-absorbing interior panels, and improved classroom sealing; spatial interventions by relocating learning activities to rooms farther from the railway; and ecological interventions by planting vegetative buffers such as dense shrubs and trees to attenuate sound and filter airborne pollutants.Such comprehensive measures would not only reduce noise and air pollution but also improve the overall environmental well-being and comfort of the school community. The case of State Elementary School 1 Rajabasa Raya thus exemplifies how environmental geography and sound ecology can intersect to inform practical, location-based solutions to noise-induced learning disruptions.

3.2 The relationship between noise and concentration in learning

The coefficient of determination value can be used to find out or predict how much influence the independent variable has on the dependent variable. However, the calculation of the coefficient of determination value can only be done if the independent variable and the dependent variable have a relationship or are correlated. This analysis serves to find out the magnitude of the contribution or influence of train noise on the concentration of learning in students at State Elementary School 1 Rajabasa Raya. The greater the result of the coefficient of determination, the greater the influence of noise on student concentration.

The coefficient of determination value is 39.94%. This result means that the contribution or influence of train noise on the concentration of learning of students at State Elementary School 1 Rajabasa Raya is 39.94%. While the remaining 60.06% can be influenced by other factors that were not examined in this study.

Table 4. Noise score categorization results and study concentration score

Range value	Category	Frequency	Percentage
Noise score categorization results			
X ≥ 21	High	22	22.45
15 ≤ X ≤ 21	Med	67	68.35
X < 15	Low	9	9.2
Total		98	100
Study concentration score			
X ≥ 23,33	High	37	37.8
17 ≤ X ≤ 23,33	Med	39	39.8
X < 17	Low	22	22.4
Total		98	100

As many as 22 students felt disturbed by the noise caused by the train when it passed and 37 students felt that the sound disturbed their concentration in learning. When the train passes, the train usually sounds the horn as a sign that the train will pass in the area. This sometimes disturbs students because it is surprising. Especially when the train passes if students are in the school exam period. The results of the correlation analysis indicate a significant and negative relationship between railway noise levels and students' concentration during classroom learning at State Elementary School 1 Rajabasa Raya. The coefficient of determination (R^2)value of 39.94% shows that nearly forty percent of students' learning concentration can be explained by variations in railway noise intensity, while the remaining 60.06% may be influenced by other factors such as classroom temperature, lighting, psychological stress, or individual learning styles. This result reinforces the notion that environmental noise exposure is a dominant external factor affecting students' attention and cognitive engagement during lessons.

From a cognitive-environmental perspective, noise acts as a competing stimulus that interferes with the brain's capacity to filter relevant information. Sudden sound peaks—such as train horns—activate the orienting reflex, forcing the brain to involuntarily redirect attention (Stansfeld & Matheson, 2003; Clark et al., 2018). This process repeatedly disrupts the student's *working memory loop*, resulting in fragmented learning and increased cognitive load (Caviola et al., 2021). Consequently, frequent interruptions accumulate over time and contribute to mental fatigue, lowering sustained attention and overall academic performance (van Kempen et al., 2010; Foraster et al., 2022). From an environmental health standpoint, noise pollution from train operations represents a form of chronic environmental stress that affects both psychological comfort and physiological regulation. Children exposed to consistent sound levels above 55 dB are at higher risk of experiencing increased cortisol levels, anxiety, and sleep disturbance, which indirectly affect classroom readiness and learning efficiency (Clark et al., 2018; Foraster et al., 2022). The present findings thus reflect not only a learning challenge but also an environmental health concern that aligns with global evidence linking school noise exposure to delayed cognitive development (European Environment Agency, 2020).

Spatially, the relationship between noise and concentration demonstrates a clear geographical dimension. Classrooms located closer to the railway line (V-A and V-B) consistently recorded both higher measured Leq values and greater reported distraction levels than classrooms farther away (V-C). This spatial variation highlights that exposure is not evenly distributed, but influenced by classroom orientation, façade structure, and local topography (Zafar et al., 2023; Gharehchahi et al., 2024). Intra-school mapping using GIS could therefore identify "acoustic hotspots"—specific zones where physical and environmental interventions would yield the greatest benefits. The educational implications are equally significant. Disruption of focus not only affects academic performance but may also reduce motivation and participation, particularly during critical assessment periods when concentration demands are highest. Teachers often report needing to pause lessons when the train passes, causing fragmented instruction and reduced teaching efficiency. Such interruptions, although brief, compound across the school day, leading to cumulative time loss and cognitive disengagement.

To mitigate these effects, a multi-layered intervention framework is necessary, including acoustic engineering measures such as the use of absorptive wall panels, ceiling tiles, and double-glazed windows to reduce internal reverberation and direct transmission; spatial zoning by repurposing classrooms most exposed to noise for non-academic activities while quieter interior rooms host intensive learning sessions; ecological buffering through vegetative barriers such as trees and shrubs around the railway perimeter to absorb sound energy, improve air quality, and create a more comfortable microclimate (Ranasinghe et al., 2019; Ow et al., 2017; Bakker et al., 2023); and behavioral adaptation by scheduling cognitively demanding subjects during quieter periods of the day and implementing mindfulness or auditory coping strategies to improve resilience to environmental stress.

From a policy and planning perspective, the findings emphasize the importance of integrating environmental health standards into educational infrastructure planning. Local governments and the Ministry of Education could adopt environmental noise mapping (following the European model, European Environment Agency (2020) as part of school zoning assessments. By identifying and classifying schools located within high-noise corridors (0–100 m from rail or major roads), municipalities can prioritize environmental remediation and funding allocation. In summary, the analysis reveals that the relationship between railway noise and students' concentration at State Elementary School 1 Rajabasa Raya is multifactorial, reflecting the interaction between environmental exposure, spatial context, and cognitive functioning. Noise is not merely an auditory issue but an environmental and educational one—requiring coordinated responses across sectors of health, urban planning, and education. Implementing spatially targeted and environmentally sensitive policies will be essential to ensure that school environments remain acoustically safe, psychologically comfortable, and supportive of students' learning potential.

The results of this study are also in line with research conducted by Gilavand & Jamshidnezhad (2016) which shows that noise has a negative impact on the learning and academic achievement of elementary school students. Noise in the classroom will significantly reduce student performance in learning how to read and write (Fernandes, et al., 2019). The statistically significant correlation found in this study between noise intensity and reduced concentration must be interpreted through both environmental-health and spatial lenses. Environmentally, noise acts as a stressor that disrupts cognitive processes central to learning—attention, working memory, and information encoding. Recent cohort evidence demonstrates that school-site traffic noise exposure is associated with slower development of working memory and attention over time, especially when noise fluctuation (peaks) is high, not just the long-term average level (Foraster et al., 2022). In practical terms, repeated train pass events—often featuring horns and brief high-level peaks—are likely to create repeated interruptions to focus and to increase mental fatigue among pupils, particularly during tasks demanding sustained attention.

The geographical distribution of noise exposure within the school compound further explains heterogeneity in concentration outcomes. Acoustic exposure is not uniform: classrooms facing the track or with windows open toward the line will receive higher instantaneous sound pressure levels and more noise fluctuations. Evidence from spatially-explicit noise studies shows that even modest differences in distance and orientation (for example, 13 m vs 40 m from a busy road) can yield differences of ~20 dB in measured sound levels, enough to markedly change speech intelligibility and cognitive load (Supriyatno, 2016; Faradiba, 2017). Mapping intra-school exposure using a combination of SLM measurements and GIS interpolation (heatmaps) could identify "hotspot classrooms" where interventions would yield the largest benefits in concentration and performance.

Finally, an integrated approach that combines environmental interventions with spatial reconfiguration is the most promising. Acoustic engineering (double-glazing, internal absorptive materials) reduces classroom transmission, while vegetated barriers and sound walls reduce outdoor source intensity and also deliver co-benefits for air pollution reduction and microclimate modulation. Importantly, these interventions can be prioritized and targeted using geospatial analysis: remediation resources directed first to the highest-exposure buffers and hotspot classrooms will be more efficient and likely to produce measurable improvements in concentration and learning outcomes. This spatial targeting approach is both evidence-based and cost-sensible for municipal education and environmental planners.

3.3 Geographical analysis and noise zonation

A geographical and spatial perspective provides an important lens for understanding railway noise exposure and its environmental implications. The location of State Elementary School 1 Rajabasa Raya in Bandar Lampung, which lies adjacent to the Rajabasa Railway Line (Tanjungkarang–Palembang route), makes it an ideal case for spatial noise mapping. At the policy level, the European Environment Agency requires member states to produce strategic noise maps for major roads, railways, and airports, which visualize the distribution of noise intensity and affected populations (European Environment Agency, 2020). In this context, Geographic Information Systems (GIS) serve as a powerful tool to overlay transportation noise data with the spatial distribution of schools or residential areas. For example, the ArcGIS Living Atlas provides updated transportation noise layers for roads and railways that allow researchers to classify schools by their exposure level (Environmental Systems Research Institute, 2023). A similar approach can be applied to Bandar Lampung: by integrating measured railway noise levels with school location data, a localized noise exposure map could identify which schools are most affected and guide targeted mitigation planning.

Noise zonation analysis can be performed using GIS buffer techniques — creating zones at specified distances (e.g., 100 m, 300 m) around railway lines to represent varying degrees of noise impact. Field measurements from sound level meters can be visualized as a heatmap showing spatial gradients of noise intensity across the school area. For instance, a study in Pontianak City, Indonesia, used Surfer 11 software to map urban school noise levels, revealing that most areas were within the 60–70 dB range, which exceeds the recommended threshold for educational zones (Supriyatno, 2016). The study also noted that proximity plays a major role, as schools located 13 meters from main roads experienced average noise levels of 72.8 dB, compared to only 52.3 dB at 40 meters distance.

Through spatial analysis, State Elementary School 1 Rajabasa Raya located within close range of the railway can be compared with other schools situated in quieter zones of Lampung Province. This comparative mapping not only demonstrates the spatial dimension of environmental noise but also strengthens the argument that school location relative to transportation infrastructure critically affects students' learning comfort. Furthermore, spatial visualization supports policymakers in setting appropriate buffer zones, planting green barriers, or developing urban zoning regulations to minimize railway noise exposure around educational facilities.

This GIS-based noise mapping approach is supported by several Indonesian studies. For example, Fariz (2022) provides a comprehensive review on urban traffic noise mapping using GIS, emphasizing the importance of representative spatial data for noise-control strategy. Krismayanti et al. (2022) analyzed the spatial distribution of railway noise along a double-track line in Madiun and found that noise levels at 7.5 m from the rails reached 80 dB(A), significantly above acceptable residential thresholds. Zuherman (2024) conducted a noise mapping study for a railway line in Bandar Lampung, showing how sound level meter data can be interpolated to reveal hot-spot zones near railway infrastructure. Arifianto et al. (2023) designed an IoT-based sensor network for real-time monitoring of railway noise, demonstrating the potential for integrating sensor data with spatial analysis for continuous exposure assessment. Pratiwi et al. (2022) measured noise from a coal train line in a residential area, reporting average outdoor noise exceeding 86 dB and recommending barriers (both vegetative and structural) as mitigation. Herdin et al. (2024) mapped how vehicle speed influences noise levels near elementary schools, highlighting how buffer distance and traffic regulation can reduce exposure.

Buraerah & Hasrul (2023) used Surfer software to spatially map heavy-vehicle noise in a residential development, identifying areas above regulatory limits and suggesting land-use planning as a mitigation tool. Atina et al. (2020) measured noise in a campus environment and found levels above the recommended Leq for educational settings, reinforcing the relevance of spatial noise assessment around learning institutions. Purnama et al. (2021) conducted a noise distribution study of Adi Sumarmo Airport and demonstrated how spatial modeling can inform regulation of residential development in affected zones. Taken together, these studies offer a robust methodological and empirical foundation for applying GIS-based railway noise mapping to State Elementary School 1 Rajabasa Raya, enabling evidence-based policy interventions such as buffer zoning, green infrastructure, or other mitigation tailored to spatial noise exposure.

4. Conclusions

This study concludes that the higher the noise intensity generated by train activities, the greater its disruptive influence on students' learning concentration at State Elementary School 1 Rajabasa Raya. The average noise levels measured in Class V—ranging from 65 to 68 dB during train passes—exceed the national noise threshold for educational areas (55 dB), indicating that the school environment has been continuously exposed to acoustic pollution. Statistical analysis revealed that train noise contributed 39.94% to the variance in students' concentration, confirming a strong negative correlation between environmental noise and learning focus.

From an environmental standpoint, railway noise represents a persistent form of pollution that directly impacts the cognitive and emotional well-being of both students and teachers. Continuous exposure to elevated noise levels leads to stress, fatigue, and reduced task engagement. These physiological and psychological effects manifest as shorter attention spans, decreased learning motivation, and lower academic performance. Teachers, similarly, experience increased difficulty maintaining classroom control and communication clarity during high-noise periods, resulting in less effective teaching processes. Geographically, the problem is intensified by the school's proximity to the railway line—approximately 25 to 35 meters—which places it within the primary exposure zone. The absence of physical noise barriers or vegetation buffers amplifies sound propagation into the classrooms. Therefore, spatial planning and environmental management must be prioritized in future interventions. Incorporating geographical noise mapping and school spatial zoning can provide valuable insights into which areas are most affected and where mitigation efforts should be concentrated.

In practical terms, this study emphasizes the importance of integrating environmental design, spatial planning, and educational management to mitigate the adverse effects of railway noise, including installing acoustic insulation and double-glazed windows to reduce indoor noise transmission; establishing vegetative barriers or sound walls to absorb and deflect sound waves from the railway; implementing spatial reallocation of classrooms and scheduling adjustments to minimize exposure during high-noise periods; and encouraging collaboration between local government, educational institutions, and railway authorities to establish noise monitoring and control programs near schools. In conclusion, railway noise is not merely an auditory nuisance but an environmental and educational challenge. Addressing it requires interdisciplinary coordination among environmental scientists, geographers, and educators. Sustainable, location-based interventions will not only enhance students' learning concentration but also improve the overall environmental quality and livability of schools situated near transportation corridors.

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Author Contribution

Both authors contributed equally to the conception, design, data collection, analysis, and writing of this study. All authors have read and approved the final manuscript for submission.

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The authors declare no conflict of interest.

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Biographies of Authors

Tesar Mahardika, Geography Education Study Program, Faculty of Teacher Training and Education, Universitas Lampung, Bandar Lampung, Lampung 35145, Indonesia.

- Email: tesarmahardika@gmail.com
- ORCID: N/A
- Web of Science ResearcherID: N/A
- Scopus Author ID: N/A
- Homepage: N/A

Sugeng Widodo, Geography Education Study Program, Faculty of Teacher Training and Education, Universitas Lampung, Bandar Lampung, Lampung 35145, Indonesia. Doctoral of Geography Education, Universitas Negeri Malang. Areas of expertise are education, educational management, geography learning.

- Email: sugengwidodo@fkip.unila.ac.id
- ORCID: 0000-0003-0739-6557
- Web of Science ResearcherID: N/A
- Scopus Author ID: 58379059500
- Homepage: https://scholar.google.com/citations?user=CyWWXnEAAAAJ&hl=en