



Ambient air quality, air pollution index, and noise baseline for environmentally responsible residential development

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ABSTRACT

Background: Peri-urban residential development can change local environmental conditions through dust generation, traffic-related emissions, equipment operation, and community noise. Baseline assessment is therefore needed before construction to distinguish existing environmental pressure from future project-related impacts. This study assesses ambient air quality and environmental noise around the planned Sunville Residence development in Paccinongang Urban Village, Somba Opu District, Gowa Regency, Indonesia.

Methods: A descriptive quantitative baseline design was used. Primary monitoring data from two strategic points were analyzed: one point within the project site and one point at the nearest settlement near a main road. Ambient air parameters included TSP/PM₁₀, SO₂, NO₂, O₃, CO, and Pb. Noise was evaluated at an internal project point and a settlement receptor. Measured values were compared with applicable Indonesian standards, and air quality was interpreted using the ISPU category. **Findings:** All ambient air pollutants were below the reported national standards. The conservative T2-BSP values represented 21.7% of the TSP/PM₁₀ standard, 25.1% of the SO₂ standard, 13.2% of the NO₂ standard, 19.4% of the O₃ standard, 11.5% of the CO standard, and approximately 1.0% of the Pb standard. ISPU values for TSP/PM₁₀, SO₂, NO₂, O₃, and CO were 22, 13, 13, 10, and 6, respectively, all categorized as Good. Noise at the internal project point was 50 dB(A), below the residential benchmark of 55 dB(A), while the nearest settlement point reached 62 dB(A), exceeding the benchmark by 7 dB(A). **Conclusion:** The study area has a favorable pre-construction air-quality baseline, but settlement noise is already above the residential standard and requires receptor-sensitive management. **Novelty/Originality of this article:** This article integrates ambient air compliance, ISPU communication, and receptor-based noise interpretation into a management-oriented baseline for environmentally responsible peri-urban housing development.

KEYWORDS: ambient air quality; air pollutant standards index; construction dust; environmental noise; residential development.

1. Introduction

Peri-urban residential growth in Indonesian metropolitan regions has intensified the need for environmental baselines that are not merely descriptive, but directly useful for environmental management, construction planning, and protection of nearby communities. The expansion of housing areas into agricultural and mixed-use urban fringes can change the local environmental condition through material transportation, land clearing, soil exposure, heavy equipment operation, increased traffic, and the emergence of permanent residential mobility. In Indonesian metropolitan settings, urban expansion and land-use

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transformation have been associated with spatial restructuring and environmental quality degradation in suburban areas, including through changes in transportation and urban activity systems (Surya et al., 2021). Evidence from Jakarta further demonstrates that outward expansion of built-up areas is associated with changes in urban environmental conditions, including worsening air pollution and urban heat-island effects (Sarker et al., 2024). In such settings, air quality and environmental noise are among the most immediate environmental components perceived by residents. They are also highly dynamic because their levels depend on traffic intensity, equipment operation, meteorological conditions, land cover, road surface condition, and the distance between emission sources and sensitive receptors. Recent research around construction-affected neighborhoods shows that construction activities and heavy-duty traffic can produce localized spatial variability and elevated PM_{2.5} concentrations near construction sites (Jaafar et al., 2024). A baseline assessment before construction is therefore essential to distinguish existing environmental conditions from future project-related changes and to design proportional mitigation measures.

Ambient air pollution and noise pollution are often addressed separately in project documentation, yet they are closely connected in the daily experience of peri-urban communities. Construction vehicles, haul trucks, generators, excavators, road traffic, and material handling can emit both airborne pollutants and acoustic energy (Jaafar et al., 2024). Dust resuspension from unpaved or disturbed surfaces may increase coarse particulate matter, while combustion processes can contribute nitrogen oxides, sulfur dioxide, carbon monoxide, and secondary pollutants. At the same time, the same activities generate intermittent or continuous noise that can disturb comfort, sleep, learning, communication, and perceived residential quality (Boakye & Adanu, 2022; Mir et al., 2022). The World Health Organization (2021) emphasized that air pollutants such as particulate matter, ozone, nitrogen dioxide, sulfur dioxide, and carbon monoxide remain major concerns for health protection, while the World Health Organization Regional Office for Europe identified environmental noise as a public-health issue that requires preventive urban planning rather than only end-of-pipe control.

In environmental impact assessment practice, baseline air and noise monitoring is important for three reasons. First, it provides a factual benchmark for determining whether the pre-project environment already experiences pressure from surrounding activities. Second, it allows regulators, developers, and communities to evaluate the incremental significance of construction and operational activities. Third, it supports the design of monitoring programs that focus on parameters most likely to change (Hong et al., 2020; Mir et al., 2022). Air quality and noise baselines also assist in the selection of management measures such as dust suppression, haul-route control, equipment maintenance, construction scheduling, temporary noise barriers, buffer vegetation, and community complaint mechanisms (Jaafar et al., 2024). The value of such baselines increases when measurement results are interpreted through nationally applicable quality standards, public-health references, and spatial receptor sensitivity (Hong et al., 2020; Jaafar et al., 2024; Mir et al., 2022).

Indonesia has developed a national regulatory framework for environmental quality management, including air-quality protection under Government Regulation No. 22 of 2021 and air-quality index communication under Minister of Environment and Forestry Regulation No. 14 of 2020. These instruments provide the regulatory basis for comparing measured ambient pollutant concentrations with national ambient air standards and for translating pollutant concentrations into the air pollutant standards index/*indeks standar pencemar udara* (ISPU), a category-based communication tool. In the context of residential development, noise is commonly assessed against the environmental noise standard for settlements, particularly the benchmark of 55 dB(A) established for residential areas in the Indonesian noise-quality framework. These standards are critical because residential areas have relatively high sensitivity compared with industrial or commercial areas.

Previous studies have demonstrated that construction activities can contribute to particulate pollution if the soil surface, stockpiles, transport routes, and demolition or

excavation activities are not properly controlled. Reviews of construction particulate matter have shown that planning decisions, on-site management, surface stabilization, and real-time monitoring can reduce dust emission risks. Broader air-quality research has also linked particulate matter and gaseous pollutants to respiratory and cardiovascular outcomes, supporting the need to minimize avoidable exposures even when baseline levels are within legal limits (Sankoh et al., 2013). In urban and peri-urban settings, coarse particles and road dust can be resuspended by vehicle movement, making traffic management and surface condition highly relevant to development control (Ewing & Dumbaugh, 2009; Medina-Ramón et al., 2008).

Noise research similarly indicates that the environmental significance of a measured level depends not only on regulatory compliance but also on receptor type, time of exposure, source characteristics, and community context. Recent evidence has associated environmental and traffic noise exposure with annoyance, sleep disturbance, mental-health outcomes, and cardiovascular risks, although the strength and certainty of evidence vary across outcomes (Hegewald et al., 2020; Münzel et al., 2014; Van Kamp et al., 2020). For example, systematic reviews have reported associations between environmental noise and cardiovascular outcomes, while updated evidence also indicates a relationship between traffic-noise exposure and sleep disturbance (Smith et al., 2022; Van Kamp et al., 2020). Evidence concerning mental health is more heterogeneous, with systematic reviews reporting possible associations between traffic noise and depression or anxiety but also emphasizing limitations in the available evidence (Hegewald et al., 2020). For housing developments, this means that the nearest settlement or existing residential receptor should be interpreted as a sensitive point even if the project area itself is relatively quiet. A site may have compliant air quality while still exhibiting localized noise pressure at receptors adjacent to roads or community activity corridors.

Comparable environmental baseline studies provide useful precedents for positioning the present research. Assessment pre-construction air quality around the proposed Yangon Outer Ring Road using PM₁₀, PM_{2.5}, NO₂, and SO₂ at multiple locations, demonstrating the value of baseline monitoring for identifying pollutants that require attention before project implementation (Ko et al., 2022). At the construction-site scale, Kim et al. (2020) combined real-time measurements with construction-activity information to identify the factors influencing dust, noise, and vibration during earthwork, demonstrating how environmental monitoring can be linked directly to construction activities and management decisions (Hong et al., 2020). More recently, Jaafar et al. (2024) investigated neighborhood air quality around active construction sites and found greater PM_{2.5} concentrations and spatial variability at locations closer to construction activities, highlighting the importance of receptor-oriented monitoring and spatial differentiation (Jaafar et al., 2024). These studies confirm the importance of baseline and receptor-specific monitoring, but their analytical emphasis generally ranges from pre-construction air-quality characterization to activity-based construction monitoring or neighborhood-scale assessment of active construction impacts. The present study builds on this literature by integrating pre-construction ambient-air compliance, ISPU-based interpretation, and receptor-differentiated noise assessment within a single peri-urban residential-development framework, thereby linking baseline conditions directly to monitoring and mitigation priorities.

The novelty of this study lies not in the routine measurement of ambient air pollutants and environmental noise, but in the integrated analytical framework used to transform conventional baseline monitoring data into a receptor-sensitive and management-oriented environmental assessment. Unlike routine environmental baseline reports that primarily present measured concentrations and determine regulatory compliance, this study combines three complementary levels of interpretation; pollutant concentrations relative to national ambient standards, ISPU-based air-quality communication, and spatially differentiated noise evaluation between the internal project area and the nearest residential receptor. This approach identifies not only whether environmental parameters comply with regulatory limits, but also which parameters and receptors should receive priority during subsequent construction activities. In particular, the framework demonstrates that a

generally favorable air-quality baseline may coexist with an already elevated noise burden at a nearby residential receptor. By translating these contrasting baseline conditions into parameter-specific mitigation priorities, adaptive monitoring indicators, and receptor-based management responses, the study extends conventional baseline assessment from a descriptive compliance exercise into a decision-support framework for environmentally responsible residential development.

Accordingly, this study addresses the following research questions; (1) What are the pre-construction concentrations of ambient air pollutants at the internal project site and the nearest residential receptor, and how do these concentrations compare with applicable national ambient air-quality standards and ISPU categories? (2) How do baseline environmental noise levels differ between the internal project site and the nearest residential receptor, and to what extent do they comply with the residential noise benchmark? (3) Which environmental parameters and receptor locations should be prioritized for construction-phase monitoring and mitigation based on the integrated interpretation of air-quality, ISPU, and noise baseline conditions? By addressing these questions, the study aims to move beyond routine compliance reporting and provide a receptor-sensitive basis for environmental management and decision-making in peri-urban residential development.

2. Methods

2.1 Study area and project context

The study was located in Paccinongang Urban Village, Somba Opu District, Gowa Regency, South Sulawesi, Indonesia, at the planned Sunville Residence residential development area. The project context is peri-urban, meaning that the site is influenced by a combination of planned housing development, nearby settlements, local road movement, and existing daily community activities. This receptor setting is important because the environmental impact of a residential project is not limited to the construction boundary. Dust and noise may travel from the project area to the nearest settlement, while existing traffic conditions near settlements may also influence baseline levels before construction begins.

Two monitoring points were used to represent the spatial contrast between the project site and a sensitive community receptor. T1-BSP was positioned within the project area, away from major roads and intensive community activities, and was therefore used to characterize the internal site baseline. T2-BSP was positioned at the nearest settlement and close to a main road corridor, representing a receptor that may already receive noise and pollutant influence from traffic and daily community mobility. The same logic was applied to the noise-monitoring points; KT1-BSP represented the quieter internal project setting, while KT2-BSP represented the nearest settlement receptor.

2.2 Research design

This study used a descriptive quantitative baseline design. The purpose was not to test a causal hypothesis through experimental manipulation or to characterize long-term population exposure, but to describe the pre-construction condition of air quality and noise at strategically selected receptor settings in a way that can be reproduced, interpreted, and used for environmental management. This approach is consistent with environmental impact assessment practice, in which measurements collected before or during project implementation provide reference conditions against which subsequent environmental changes can be evaluated (Zítková et al., 2022). The design is appropriate for environmental impact assessment because it establishes the initial environmental status before the implementation of land preparation, equipment mobilization, construction traffic, and operational residential activity. Accordingly, the design should be understood as a spatially

and temporally bounded screening assessment rather than a continuous or seasonally representative monitoring program.

The analytical approach followed four sequential steps. First, primary measurement results were organized by parameter and monitoring point. Second, each measured value was compared with the relevant environmental quality standard. Third, the air-quality measurements were summarized through the ISPU category to communicate the overall air-quality condition, consistent with Indonesia's national ISPU framework. Fourth, the results were interpreted with respect to receptor sensitivity, potential construction-phase pressure, and environmental management needs. This sequence follows the logic that environmental monitoring should progress from measurement and compliance assessment toward interpretation and practical environmental management.

2.3 Ambient air quality parameters and measurement basis

Ambient air quality was assessed using key pollutants commonly relevant to construction and peri-urban development; total suspended particulate matter interpreted as TSP/PM₁₀, sulfur dioxide (SO₂), nitrogen dioxide (NO₂), photochemical oxidants as ozone (O₃), carbon monoxide (CO), and lead (Pb). These parameters were selected because they can represent dust resuspension, fuel combustion, traffic influence, secondary oxidant formation, and trace metal risk. The laboratory results also included measurement methods based on Indonesian National Standards, including SNI 7119-3:2017 for particulate matter, SNI 7119-7:2017 for SO₂, SNI 7119-2:2017 for NO₂, SNI 19-7119.8-2005 for O₃, SNI 7119.10:2011 for CO, and SNI 19-7119.4-2005 for Pb.

The two monitoring points were compared against the national ambient air quality standards reported in the baseline document. Because several results were expressed as less-than detection values, the analysis used the reported detection limit as a conservative value. This approach avoids underestimating potential exposure and is commonly acceptable for screening interpretation when the objective is to establish whether the parameter is clearly below the standard.

2.4 Noise measurement procedure and receptor classification

Environmental noise was assessed to characterize the sound environment before construction (Smith et al., 2022). The baseline document reported noise measurements at the project site and the nearest settlement, using SNI-based measurement procedures and comparing the results with the residential quality standard. The monitoring was conducted on 3 June 2025 in two time sessions from morning to late morning. The internal project point was intended to represent natural or low-activity noise conditions, while the settlement point was intended to represent the nearest receptor exposed to road traffic and community activity.

The residential receptor classification is central to interpretation. Although a project-site measurement may appear compliant, the environmental significance of noise is determined by where people live, rest, communicate, and carry out daily activities. Therefore, the nearest settlement point was given particular attention. The measured value was compared with the residential standard of 55 dB(A). The exceedance was reported as the arithmetic difference between measured Leq and the benchmark. The study also acknowledges that decibels are logarithmic; consequently, a 7 dB(A) exceedance should not be interpreted as a trivial linear increase.

2.5 Regulatory benchmarking and ISPU conversion

Ambient air concentrations were compared with the national ambient air quality standards used in the baseline report and aligned with the framework of Government Regulation No. 22 of 2021. The compliance ratio was calculated as the measured concentration divided by the standard and multiplied by 100. A value below 100 percent

indicates that the measured concentration is below the reported standard, while values approaching 100 percent would indicate a need for closer attention even if the parameter remains legally compliant.

The ISPU interpretation followed the Indonesian air-pollutant index framework under Minister of Environment and Forestry Regulation No. 14 of 2020. The baseline document classified ISPU values into five categories; Good, Moderate, Unhealthy, Very Unhealthy, and Hazardous. The ISPU results were already calculated in the baseline document using linear interpolation. This study used those calculated ISPU values to identify the dominant parameter influencing the index and to support public-communication interpretation.

2.6 Data analysis and presentation

Data analysis consisted of descriptive statistics, standard comparison, percentage-of-standard calculation, and qualitative interpretation of environmental management implications. The maximum observed value between the two air-monitoring points was used for conservative graphical presentation. For air quality, the analysis emphasized both absolute concentration and percentage of the standard because the percentage format makes comparison across parameters easier. For ISPU, the analysis emphasized index value and category. For noise, the analysis emphasized both compliance and receptor sensitivity.

Results were presented in tables and figures to support international paper readability. Tables provide the numerical basis for compliance, while figures communicate relative environmental pressure. The discussion then translates the technical results into planning implications; dust control, equipment and traffic management, noise scheduling, receptor communication, buffer design, and adaptive monitoring. This structure was selected to ensure that the study is useful not only for reporting baseline conditions but also for guiding environmental governance during residential development.

2.7 Monitoring design limitations

The monitoring design has several limitations that should be considered when interpreting the baseline results. First, the assessment relied on two strategically selected monitoring locations: an internal project-site point and the nearest residential receptor. Although these locations capture the principal spatial contrast relevant to project management, they do not represent the full spatial variability of air quality and environmental noise across the wider peri-urban area. Second, the monitoring campaign was temporally limited rather than repeated or continuous. Environmental noise monitoring was conducted on a single day, 3 June 2025, during two sessions from morning to late morning, while the available ambient-air data represent discrete baseline measurements rather than continuous time series. Consequently, variation across other times of day, weekdays and weekends, seasons, meteorological conditions, traffic intensity, and community activity could not be fully characterized. Third, the analysis relied on reported laboratory measurements and existing ISPU calculations rather than continuous real-time monitoring. Accordingly, the results are intended as a screening-level pre-construction baseline for regulatory comparison, receptor prioritization, and environmental management planning, rather than as a comprehensive assessment of long-term population exposure or seasonal environmental variability.

3. Results and Discussion

3.1 Monitoring-point context and receptor setting

The baseline monitoring design captured two contrasting environmental settings. T1-BSP was located inside the project site and relatively distant from the main road and intensive public activity, whereas T2-BSP was located at the nearest settlement close to the main corridor road. These locations represent the internal project-site baseline and the

nearest residential receptor, respectively. The two monitoring points were therefore retained as spatially distinct baseline receptors rather than combined into a single site average.

3.2 Ambient air pollutant concentrations

The measured ambient air quality parameters were below the reported national ambient air quality standards at both monitoring points. TSP/PM₁₀ was 43.09 µg/m³ at T1-BSP and 49.90 µg/m³ at T2-BSP against a standard of 230 µg/m³. SO₂ was 26.68 µg/m³ at T1-BSP and 37.63 µg/m³ at T2-BSP against a standard of 150 µg/m³. NO₂ was 20.80 µg/m³ at T1-BSP and 26.43 µg/m³ at T2-BSP against a standard of 200 µg/m³. O₃ and CO were reported below detection limits of 29.16 µg/m³ and 1,146.0 µg/m³, respectively, and Pb was reported below 0.020 µg/m³ at both points. For conservative screening only, these detection-limit values were used as upper-bound inputs when calculating percentage-of-standard ratios. Table 1 summarizes the complete parameter-by-point dataset, units, reported standards, conservative ratios, and analytical methods.

For TSP/PM₁₀, SO₂, and NO₂, T2-BSP recorded higher concentrations than T1-BSP. O₃ and CO were reported at the same conservative detection-limit values at both points, and Pb was below the reported detection limit at both points. All measured or conservatively interpreted concentrations remained below the reported national standards.

Table 1. Ambient air-quality measurements, reported standards, conservative compliance ratios, and analytical methods at the Sunville Residence baseline monitoring points

Parameter	T1-BSP	T2-BSP	Unit	Standard	T1/standard (%)	T2/standard (%)	Method
TSP/PM ₁₀	43.09	49.90	µg/m ³	230	18.7	21.7	SNI 7119-3:2017
SO ₂	26.68	37.63	µg/m ³	150	17.8	25.1	SNI 7119-7:2017
NO ₂	20.80	26.43	µg/m ³	200	10.4	13.2	SNI 7119-2:2017
O ₃	< 29.16	< 29.16	µg/m ³	150	< 19.4	< 19.4	SNI 19-7119.8-2005
CO	< 1146	< 1146	µg/m ³	10,000	< 11.5	< 11.5	SNI 7119.10:2011
Pb	< 0.020	< 0.020	µg/m ³	2	< 1.0	< 1.0	SNI 19-7119.4-2005

Note: O₃, CO, and Pb were below their reported detection limits. Detection-limit values were used only as conservative upper bounds for screening ratios; "TSP/PM₁₀" is retained from the baseline report.

3.3 Compliance ratio relative to ambient standards

The percentage-of-standard calculation confirms that all assessed air pollutants were well below their respective reported limits. At T2-BSP, the quantified ratios were 21.7% for TSP/PM₁₀, 25.1% for SO₂, and 13.2% for NO₂. For parameters reported below detection limits, the conservative upper-bound ratios were < 19.4% for O₃, < 11.5% for CO, and < 1.0% for Pb. As shown in Figure 1, SO₂ had the highest relative concentration, followed by TSP/PM₁₀, while every pollutant remained far below the 100% compliance threshold. Thus, none of the assessed pollutants exceeded 25.1% of its respective reported ambient-air standard at T2-BSP.

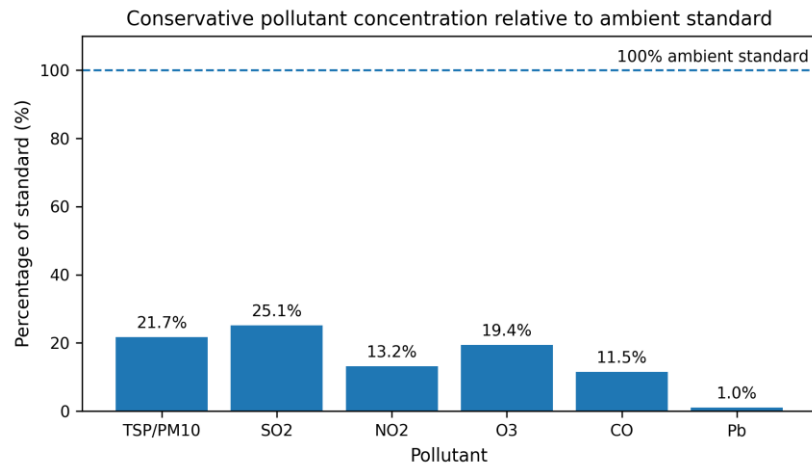


Fig. 1. Conservative upper-bound pollutant concentration at T2-BSP relative to the reported ambient air-quality standards; detection-limit values are used for non-detects

3.4 ISPU category and dominant parameter

The ISPU calculation produced a Good category for all parameters included in the reported ISPU assessment. Figure 2 shows that TSP/PM₁₀ had the highest ISPU value (22), followed by SO₂ and NO₂ (13 each), O₃ (10), and CO (6). All values remained below the Good-to-Moderate category threshold of 50. Table 2 presents the complete set of reported ISPU inputs and categories; Pb is reported separately in Table 1 because it was not included in the source ISPU calculation. TSP/PM₁₀ was therefore the dominant parameter in the baseline ISPU profile, although it remained within the Good category.

Table 2. ISPU results and air-quality categories based on the conservative baseline concentrations used in the reported calculation

Parameter	Conservative concentration ($\mu\text{g}/\text{m}^3$)	ISPU	Category
TSP/PM ₁₀	49.90	22	Good
SO ₂	37.63	13	Good
NO ₂	26.43	13	Good
O ₃	29.16	10	Good
CO	1,146	6	Good

Note: Pb was not part of the reported ISPU calculation and is therefore reported in Table 1 only. For O₃ and CO, detection-limit values were used conservatively in the reported ISPU calculation.

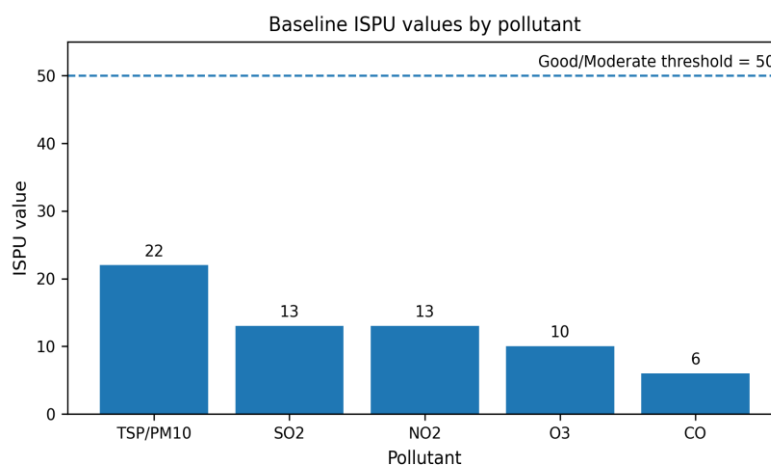


Fig. 2. Baseline ISPU values by pollutant relative to the Good-to-Moderate category threshold

3.5 Environmental noise baseline

The internal project point KT1-BSP recorded 50 dB(A), below the residential benchmark of 55 dB(A), whereas KT2-BSP at the nearest settlement recorded 62 dB(A), exceeding the benchmark by 7 dB(A). Figure 3 illustrates this contrast relative to the 55 dB(A) reference line, and Table 3 reports the receptor setting, measured Leq, benchmark, difference from the benchmark, and compliance status for both monitoring points. The two locations differed by 12 dB(A), with the higher level occurring at the residential receptor near the main road corridor.

Table 3. Baseline noise levels, receptor settings, residential benchmark, differences, and compliance status

Monitoring point	Receptor setting	Leq dB(A)	Limit dB(A)	Difference dB(A)	Status
KT1-BSP	Inside project site, away from main road	50	55	-5	Compliant
KT2-BSP	Nearest settlement, near main corridor road	62	55	+7	Above residential standard

Note: Positive differences indicate exceedance and negative differences indicate values below the benchmark. Leq values reflect the reported monitoring sessions on 3 June 2025.

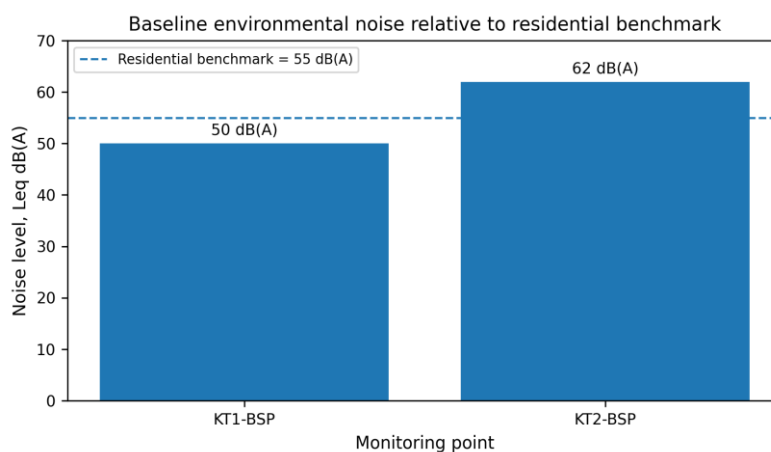


Fig. 3. Baseline environmental noise levels at KT1-BSP and KT2-BSP relative to the 55 dB(A) residential benchmark

3.6 Integrated air-noise baseline profile, meaning of a favorable air-quality baseline, and TSP/PM₁₀ and construction dust as the main air-quality concern

The integrated baseline profile shows two contrasting conditions; All assessed ambient air pollutants were below the reported standards and classified as Good by ISPU. Meanwhile, environmental noise was compliant at KT1-BSP but above the residential benchmark at KT2-BSP. These contrasting measurements form the empirical basis for the receptor-sensitive interpretation developed in the Discussion

The favorable air-quality baseline should be interpreted in relation to recent pre-construction and construction-monitoring evidence rather than as evidence that future environmental risk is negligible. Ko et al. (2022) demonstrated that pre-construction monitoring at multiple locations can identify spatial differences in ambient pollutant concentrations and provide an evidence base for identifying parameters requiring attention before project implementation. Recent study showed that environmental conditions around construction sites can vary according to construction activities and that monitoring of particulate matter and other environmental pollutants can support activity-specific environmental management (Hong et al., 2020). Jaafar et al. (2024) similarly reported

greater PM_{2.5} concentrations and spatial variability at monitoring locations closer to active construction activities, highlighting the importance of receptor-oriented interpretation.

The present findings follow this spatially differentiated pattern; overall ambient air quality was compliant with the applicable standards, but the settlement-side monitoring point recorded somewhat higher TSP, SO₂, and NO₂ concentrations than the internal project-site point. The relative compliance profile in Figure 1 and the ISPU profile in Figure 2 reinforce this interpretation by showing that the monitored pollutants remained below the applicable regulatory or ISPU-category thresholds despite differences in their relative concentrations. The present study extends those baseline approaches by combining regulatory compliance with ISPU communication and a paired internal-site versus residential-receptor comparison. Accordingly, the Good ISPU status should be treated as a performance baseline to be preserved during construction, not as a reason to reduce preventive control.

Although SO₂ had the highest percentage-of-standard ratio at T2-BSP, TSP/PM₁₀ had the highest ISPU value and is more directly linked to construction activities such as earthwork, material handling, exposed soil, and vehicle movement. This interpretation is consistent with Araujo et al. (2025), who showed that particulate concentrations vary across earthwork, structural, and finishing phases of residential construction, and with Adelodun et al. (2021) and Li et al. (2022), who emphasized that construction-dust risk depends strongly on planning, surface stabilization, and on-site management. Thus, the low pre-construction TSP/PM₁₀ concentration does not imply a low construction-phase dust risk (Islam et al., 2023). The practical implication is to concentrate particulate controls during activity windows most likely to disturb soil and resuspend dust. Measures such as wetting exposed surfaces, covering transported materials, wheel washing, stabilizing access roads, restricting vehicle speed, protecting inactive soil surfaces, and separating stockpiles from residential receptors are consistent with the control approaches summarized (An, 2024; Nizhelskiy, Kazeev, Vilkova, Fedorenko, & Kolesnikov, 2025; Siyamsih, 2024).

3.7 Gaseous pollutants and traffic-related emission control

SO₂, NO₂, CO, and O₃ were all well below the reported ambient air-quality standards, but the higher SO₂ and NO₂ values at T2-BSP indicate a spatial gradient toward the road-adjacent settlement receptor. Recent research demonstrates that traffic activity can produce substantial spatial and temporal variation in local air pollution, particularly for traffic-related NO₂ and particulate matter near roads (An, 2024; Nizhelskiy et al., 2025; Siyamsih, 2024). Evidence from Jakarta likewise indicates substantial spatial variation in NO₂, SO₂, and CO, with traffic density being associated particularly with elevated NO₂ concentrations, while meteorological conditions influence pollutant dispersion (Nizhelskiy et al., 2025).

Road-dust resuspension is also recognized as an important source of particulate pollution, with its magnitude influenced by road conditions, meteorology, and traffic characteristics (Nizhelskiy et al., 2025). Because the present study used discrete measurements at only two locations, however, the T2-BSP elevation should be interpreted as a spatial association consistent with the road-side setting rather than as direct source attribution (Velásquez Ramírez et al., 2025). This interpretation supports traffic- and equipment-focused prevention during construction, including equipment maintenance, minimizing unnecessary idling, staging deliveries, and selecting haul routes that reduce exposure at the settlement receptor. NO₂ and CO can be retained as supporting indicators of combustion-related activity, while TSP remains the more direct indicator of construction-related particulate and dust conditions.

3.8 Noise exceedance at the nearest settlement

As shown in Figure 3, the clearest receptor contrast occurred for environmental noise; KT2-BSP was 12 dB(A) higher than KT1-BSP and exceeded the residential benchmark by 7

dB(A). This result is comparable with Mahajan et al. (1996), who reported generally acceptable ambient conditions alongside localized noise exceedances, and with Okafor et al. (2023), who found marked spatial and temporal differences in combined air-pollution and noise measurements between activity areas and control locations. The similarity across these studies reinforces the importance of interpreting noise at the receptor level rather than relying on a project-site average.

The fact that the settlement receptor was already above the residential benchmark before construction is particularly important for impact attribution. It indicates that the project would be introduced into an environment with an existing acoustic burden, rather than into an acoustically unaffected setting. Consequently, any subsequent increase in noise should be evaluated as an incremental contribution to the pre-existing condition. This finding supports preventive measures such as equipment and source control, temporary acoustic barriers or other path controls, appropriate construction scheduling, and advance communication with residents (Mir et al., 2022). The public-health relevance of limiting additional exposure is supported by recent systematic-review evidence linking environmental noise with sleep disturbance and other adverse health outcomes (Smith et al., 2022; Van Kamp et al., 2020).

3.9 Integrated mitigation for air and noise during construction

The combined air-noise pattern also supports an integrated environmental-management approach. Recent construction-environment research demonstrates that particulate pollution and acoustic impacts can occur simultaneously around construction activities and may vary according to activity type, source proximity, and receptor location (Hong et al., 2020; Jaafar et al., 2024). The present study adds a pre-construction perspective by pairing ambient-air compliance and ISPU status with receptor-differentiated noise, showing that different environmental components can require different management priorities within the same development area.

Accordingly, activities that simultaneously generate dust, exhaust emissions, and noise, such as truck movement, equipment operation, and material unloading, should be addressed through coordinated controls rather than isolated single-parameter actions. Construction-management measures may therefore include scheduled deliveries, designated haul routes, road wetting, speed restrictions, covered loads, equipment inspection and maintenance, no-idling practices, temporary acoustic barriers, and appropriate working-hour limits (Hong et al., 2020; Mir et al., 2022). These measures can be linked to the receptor-specific indicators summarized in Table 4. The matrix retains all measured ambient-air variables, including Pb as a separate trace-metal parameter, together with environmental noise and receptor-response indicators, ensuring that each monitored variable is explicitly incorporated into the environmental-management interpretation.

Table 4. Integrated environmental management matrix covering monitored air-quality variables, noise, and receptor-response indicators

Issue	Baseline indication	Construction-phase control	Monitoring indicator
Dust/TSP	TSP/PM ₁₀ is the dominant ISPU parameter and remains below the reported standard	Watering, wheel washing, covered stockpiles, stabilized access, speed control	TSP/PM ₁₀ concentration and visible dust complaints
Gaseous air pollutants	SO ₂ and NO ₂ are quantified below standards; O ₃ and CO are below detection limits and conservatively	Equipment maintenance, no idling, low-sulfur fuel, staged mobilization	SO ₂ , NO ₂ , O ₃ , CO, and traffic activity log

Lead (Pb)	screened below standards < 0.020 µg/m ³ at both points; conservative upper bound < 1.0% of the reported standard	Maintain general equipment/material source controls; reassess if the source profile changes	Pb concentration when source conditions warrant
Settlement noise	KT1-BSP = 50 dB(A); KT2-BSP = 62 dB(A), or +7 dB(A) above the residential benchmark	Time restrictions, equipment mufflers, temporary barriers, haul-route management	Leq dB(A), complaint records, construction schedule compliance
Public receptors	Nearest settlement is the sensitive receptor for cumulative project-related pressure	Community information, hotline, grievance resolution, buffer planting	Response time and resolved complaints

Note: This management synthesis retains each monitored air-quality variable, environmental noise, and receptor-response indicators, while distinguishing quantified results from detection-limit upper bounds.

3.10 Adaptive monitoring and threshold-based response

The baseline should be translated into an adaptive environmental monitoring program. Adaptive monitoring allows the frequency, duration, and spatial intensity of monitoring to be increased when higher-risk construction activities occur, meteorological conditions favor pollutant dispersion or accumulation, community complaints are received, or measured concentrations approach predefined management thresholds. This approach is particularly relevant to construction environments because pollutant levels can change rapidly with construction activities, equipment use, weather conditions, and source–receptor relationships. Empirical research has shown that real-time monitoring indices can be linked to construction activities and used to reduce exceedances of dust and noise criteria, while more recent studies demonstrate the value of spatially and temporally resolved monitoring around construction sites (Jaafar et al., 2024). Construction-noise research likewise emphasizes assessment, prediction, control, and monitoring as interconnected components of construction environmental management (Ljungman et al., 2019).

A threshold-based response system may include several operational levels. At the first level, routine preventive controls are applied during normal construction activities. At the second level, visible dust, increased truck movements, unusual equipment activity, or elevated noise triggers immediate field inspection and corrective action. At the third level, measured concentrations approaching applicable standards, repeated elevated measurements, or recurring community complaints trigger a formal review of work methods and control effectiveness. At the fourth level, confirmed exceedances or unresolved environmental complaints require escalation, which may include temporary modification of the relevant activity, intensified monitoring, implementation of additional controls, and corrective reporting. Such a tiered system converts baseline information into an auditable and responsive environmental-management mechanism, rather than treating baseline monitoring as a one-time compliance exercise.

3.11 Implications for peri-urban residential planning

The findings have implications beyond the immediate project site. Peri-urban housing development often occurs in areas where road infrastructure, drainage, settlements, agricultural land, and new construction activities interact (Permana & Winarso, 2025).

Environmental baselines should therefore be used not only to satisfy regulatory requirements but also to guide site planning. Road access, buffer zones, vegetation, construction staging, and community interface design should be aligned with the spatial pattern of sensitive receptors (Rienda & Alves, 2021; Munawar et al., 2017).

For Sunville Residence, the nearest settlement and road corridor form the critical environmental interface. Buffer planting, controlled access points, minimized truck conflict with residential roads, and careful placement of noisy temporary facilities can reduce future exposure. During operation, residential traffic and community activity may also change the noise and air-quality profile. Therefore, operational planning should include traffic circulation, green corridors, pedestrian safety, and maintenance of internal roads to minimize dust resuspension and unnecessary noise.

The baseline also supports a phased management logic across the project lifecycle. Before construction, the most important action is to preserve the baseline through route selection, site fencing, stockpile placement, and communication with the nearest settlement. During land clearing and earthwork, management should shift toward short-cycle controls such as daily road wetting, inspection of wheel-wash facilities, and rapid response to visible dust. During structural construction, the dominant issues may move toward truck circulation, equipment noise, generator operation, and worker-vehicle interaction. During operation, the emphasis should again change, focusing on internal road maintenance, traffic calming, green-buffer survival, drainage cleanliness, and the avoidance of nuisance from permanent residential activity. This staged interpretation is important because a single baseline number is not a management plan; it becomes useful only when translated into different decisions at different project phases.

A receptor-sensitive interpretation also means that the nearest settlement should be treated as the reference location for accountability rather than as a secondary point. The internal project point is useful for understanding the original site condition, but community acceptance will depend on what happens at houses, access roads, and public spaces outside the project fence. Therefore, the settlement boundary should be used for routine communication, complaint verification, and follow-up monitoring when high-risk activities occur. Baseline exceedance for noise does not automatically mean that the project caused the problem, but it does mean that any additional construction noise could be perceived as cumulative pressure. In this context, transparent documentation of working hours, noisy activity schedules, and mitigation actions can reduce misunderstanding and provide evidence for corrective decisions.

Taken together, the comparison with previous studies supports using the nearest settlement as the primary accountability receptor during construction. The internal point remains important as the reference condition for the project footprint, but the settlement point better captures the location where existing road influence and future project activities may accumulate. This receptor-based interpretation is consistent with the spatial contrasts reported by Mahajan et al. (1996) and Okafor et al. (2023) and strengthens the use of baseline monitoring as a decision-support tool rather than a compliance-only exercise.

3.12 Regulatory, public-health significance, limitations, and future research

The study illustrates how Indonesian regulatory standards and international public-health perspectives can be used together. National standards determine legal compliance and environmental permitting relevance, while international public-health literature helps interpret why low pollutant and noise levels should be preserved. This is particularly important because air pollution and noise have no strict social boundary. Their effects depend on exposure duration, population sensitivity, and cumulative interaction with other stressors.

The ISPU framework is useful for communicating air-quality status to non-specialist stakeholders. A Good category is easy to understand and can support public reassurance. However, communication should remain careful; Good baseline air quality does not guarantee that future construction will remain acceptable without management. For noise,

the exceedance at the settlement receptor should be communicated transparently and used as a reason to implement additional controls from the beginning of construction rather than waiting for complaints.

This study has several limitations. The baseline assessment was based on two strategically selected monitoring locations and therefore does not capture the full spatial variability of environmental conditions across the wider peri-urban area. In addition, the monitoring campaign was temporally limited; environmental noise was measured on a single day during two morning-to-late-morning sessions, while the available air-quality data represent discrete baseline measurements rather than continuous observations. Air quality and environmental noise may vary substantially according to time of day, weekday-weekend patterns, season, meteorological conditions, traffic intensity, and surrounding activities. The study also relied on reported laboratory results and existing ISPU calculations rather than continuous real-time monitoring. Consequently, the findings should be interpreted as a screening-level pre-construction baseline and management-planning reference rather than as a comprehensive characterization of seasonal variability or long-term population exposure.

Future research should include repeated measurements across dry and wet seasons, continuous noise monitoring at the settlement boundary, traffic counting, meteorological observations, and dispersion or noise propagation modeling. A before-during-after construction monitoring design would allow clearer attribution of changes to project activities. Community perception surveys could also be added to understand whether measured noise and dust correspond with residents' perceived disturbance. Such integration would strengthen the social legitimacy of environmental management.

4. Conclusions

The baseline assessment shows that ambient air quality around the planned Sunville Residence development in Paccinongang Urban Village was generally good before construction, with TSP/PM₁₀, SO₂, NO₂, O₃, CO, and Pb all below the reported national ambient air standards at both monitoring points. The ISPU results also placed all assessed parameters in the Good category, with TSP/PM₁₀ as the dominant parameter but still far below the Moderate threshold, indicating that air quality should be maintained through preventive dust and emission controls. In contrast, the noise baseline shows a more sensitive issue; the internal project point recorded 50 dB(A), below the residential benchmark, while the nearest settlement point recorded 62 dB(A), exceeding the residential standard by 7 dB(A), likely due to road and community activity. Therefore, construction should avoid adding cumulative noise burdens through scheduling restrictions, equipment maintenance, temporary barriers, haul-route management, and a community complaint mechanism. The main contribution of this paper is its integrated interpretation of ambient air quality, ISPU status, and receptor-sensitive noise conditions, showing that compliant air quality and partially non-compliant noise can coexist in the same peri-urban development area. Consequently, environmental management should be component-specific; air-quality management should maintain Good ISPU status, while noise management should prioritize the nearest settlement receptor as the basis for responsible construction and long-term residential planning.

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Author Contribution

Conceptualization, A.C. and N.R.; Methodology, M.; Formal Analysis, M.; Data Curation, N.R.; Writing - Original Draft Preparation, A.C.; Writing - Review & Editing, A.C. and N.R.; Visualization, M.; Supervision, A.C.; Project Administration, N.R.

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Not available.

Data Availability Statement

The data supporting the findings of this study are derived from the project environmental baseline document and publicly available climate data sources cited in the manuscript. Additional raw project data may be subject to project-owner permission.

Conflicts of Interest

The authors declare no conflict of interest.

Declaration of Generative AI Use

During the preparation of this work, the authors used generative artificial intelligence to assist in language structuring, academic organization, and formatting. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

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