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Determinant of $PM_{2.5}$ and PM_{10} Concentrations in Residential Areas of Sungai Pinang and Samarinda Ulu Districts, Samarinda City, Indonesia

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A B S T R A C T

Indoor air quality significantly affects occupants' health, particularly by increasing the risk of respiratory disorders. This analytical observational study employed a cross-sectional design to examine the relationship between the physical characteristics of house and their surrounding environment and the concentrations of $PM_{2,5}$ and PM_{10} particulates in Sungai Pinang and Samarinda Ulu Districts. A total of 151 houses were selected using purposive sampling. The variables investigated included wall condition, ventilation, ceiling condition, type of cooking fuel, occupancy density, and the presence of plants. $PM_{2,5}$ and PM_{10} concentrations were measured using a Dust Sampler, and the data were analyzed using univariate and bivariate analyses (Mann-Whitney and Kruskal-Wallis tests). The results showed variations in particulate concentrations between the two study locations. At he first location, the mean $PM_{2,5}$ and PM_{10} concentrations were 9 µg/m³ and 52 µg/m³ respectively (temperature 32.15°C; relative humidity 71%). At the second location, the mean concentrations were 12 µg/m³ and 71 µg/m³ (temperature 33.14°C; relative humidity 72%). Most houses had non-permanent walls (72.8%) and ventilation that did not meet the recommended health standards (99.3%). Bivariate analysis indicated that wall conditions was the only variable significantly associated with $PM_{2.5}$ ($p=0.040$) and PM_{10} ($p=0.049$) concentrations. No statistically significant associations were observed for the other variables. In conclusion, wall condition is an important determinant of indoor particulate concentrations. Improving building quality, particularly wall construction, along with strengthening environmental health education, may help reduce particulate exposure and its associated health risks within the community.

Kualitas udara dalam ruang sangat memengaruhi kesehatan penghuni, khususnya risiko gangguan pernapasan. Penelitian observasional analitik dengan desain *cross-sectional* ini bertujuan menganalisis hubungan antara kondisi fisik rumah dan lingkungan sekitar dengan konsentrasi partikulat $PM_{2,5}$ dan PM_{10} di Kecamatan Sungai Pinang dan Samarinda Ulu. Studi melibatkan 151 rumah yang dipilih melalui *purposive sampling*. Variabel yang diteliti mencakup kondisi dinding, ventilasi, langit-langit, jenis bahan bakar memasak, kepadatan hunian, dan keberadaan tanaman. Konsentrasi $PM_{2,5}$ dan PM_{10} diukur menggunakan alat *Dust Sampler*, kemudian data dianalisis secara univariat dan bivariat (uji Mann-Whitney dan Kruskal-Wallis). Hasil penelitian menunjukkan adanya variasi konsentrasi di dua lokasi penelitian. Di lokasi pertama, rata-rata $PM_{2,5}$ dan PM_{10} adalah 9 µg/m³ dan 52 µg/m³ (suhu 32,15°C; kelembapan 71% RH). Sementara di lokasi kedua, rata-rata sebesar 12 µg/m³ dan 71 µg/m³ (suhu 33,14°C; kelembapan 72% RH). Mayoritas rumah memiliki dinding non-permanen (72,8%) dan ventilasi yang tidak memenuhi syarat kesehatan (99,3%). Analisis bivariat mengungkapkan bahwa hanya kondisi dinding yang memiliki hubungan signifikan terhadap konsentrasi $PM_{2,5}$ ($p=0,040$) dan PM_{10} ($p=0,049$). Variabel lainnya tidak cukup bukti untuk menunjukkan hubungan yang signifikan secara statistik. Kesimpulannya, kondisi fisik dinding merupakan faktor krusial yang memengaruhi konsentrasi partikulat di dalam rumah. Oleh karena itu, diperlukan upaya perbaikan kualitas fisik bangunan serta peningkatan edukasi kesehatan lingkungan guna meminimalisir risiko paparan partikulat dan dampak kesehatan bagi masyarakat.

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1. Introduction

Air plays an essential role in maintaining ecosystem balance and human health; however, its quality may change due to pollution caused by the release of pollutants in the form of gases and fine particles into the atmosphere over prolonged period of times (Ismiyati et al., 2014). Human activities are the primary sources of air pollution, particularly fuel combustion from transportation, industrial processes, and waste burning activities. The transportation sector is recorded as the largest contributor to urban air pollution, followed by industrial activities and waste combustion (Firdausy et al., 2020). Emissions generated from these activities can enter residential environments through natural ventilation, doors, and windows, thereby affecting indoor air quality (EAQ, 2023).

Air pollutants in the form of Particulate Matter (PM), particularly $PM_{2.5}$ and PM_{10}, have become serious concerns due to their direct impacts on environmental quality and human health. $PM_{2.5}$ particles are extremely small and can penetrate deep into the respiratory tract, while PM_{10} consists of a mixture of dust, smoke, and other solid particles that can be inhaled (Naimah et al., 2024; Wulan et al., 2024). Exposure to $PM_{2.5}$ and PM_{10} may cause health problems, particularly respiratory disorders, including coughing, asthma, reduced lung function, and lung cancer (Pertiwi et al., 2024). Air pollution occurs not only outdoors but also indoors, where it may have a greater impact because humans spend approximately 80–90% of their time inside houses (Lewis, 2022).

Indoor air quality is influenced by various factors, including building materials and construction, ventilation conditions, occupancy density, temperature, humidity, ceilings, and household activities such as cooking and fuel use (Febriyanti, 2014; Guercio et al., 2021). The use of cooking fuels and mosquito coils also contributes to increased indoor pollutant concentrations (Fajrianti, 2022). The presence of plants inside and around houses may help reduce pollutant concentrations because plants can absorb dust particles and harmful gases while producing oxygen that contributes to improved air quality (Tambunan et al., 2024). Physical housing conditions, such as wall type, ceiling condition, ventilation, occupancy density, smoking behavior among family members, and the availability of surrounding vegetation, influence the infiltration and accumulation of indoor air pollutants (Putri, A. M., et al., 2022). Previous studies have reported that indoor $PM_{2.5}$ and PM_{10} concentrations in several areas have exceeded the quality standards established by Indonesian Ministry of Health Regulation No. 02 of 2023, potentially posing health risks to household occupants (Hikmah, 2022; Mareta, 2022).

A house serves as both a shelter and the primary space for family activities and interactions; therefore, its environmental quality greatly determines the health status of its occupants (Dian, 2017). High occupancy density and inadequate ventilation that does not meet healthy housing standards may result in poor air circulation, increased humidity, and suboptimal indoor temperature, creating favorable conditions for the growth of bacteria that cause acute respiratory infections (ARI). Physical housing conditions characterized by humidity, dust accumulation, and inadequate natural lighting may further increase the risk of respiratory disorders (Widiati, 2024). Data from the Samarinda City Health Office indicated that the prevalence of ARI was 4.16% in 2024, demonstrating that respiratory health risks remain a concern.

Previous studies have shown that indoor air quality is influenced by physical housing environmental factors, including ventilation, occupancy density, humidity, temperature, flooring materials, and lighting conditions, which are associated with health problems such as pneumonia and acute respiratory infections (Atmawati et al., 2022; Bahri et al., 2022). Other studies have also found that occupant activities, ventilation conditions, and indoor environmental factors are associated with $PM_{2.5}$ concentrations as an indicator of indoor air quality (Romadoni, 2023;

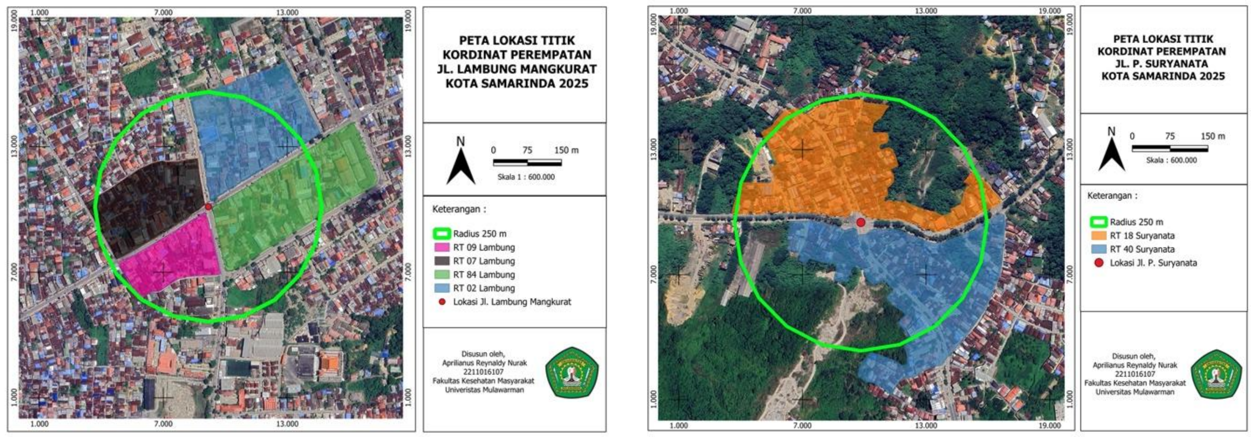
Syafei & Kurnianto, 2023). These findings indicate that indoor air quality is the result of interactions between building characteristics and occupant activities.

However, previous studies still have limitations in their analytical scope, as most studies have focused solely on the relationship between environmental factors and disease incidence or have examined a single pollutant without simultaneously comparing $PM_{2.5}$ and PM_{10}. In addition, housing characteristics such as wall and ceilings conditions, cooking fuel type, occupancy density, and surrounding vegetation have rarely been analyzed comprehensively in relation to indoor particulate concentrations. Furthermore, most previous studies have been conducted in urban settings with environmental characteristics that differ substantially from those of East Kalimantan, a region characterized by a humid rain forest climate with consistently high rainfall and humidity throughout the year (Subagio & Herliani, 2019). These climatic conditions may influence the behavior of airborne particulates by affecting deposition, suspension and resuspension processes, potentially resulting in different patterns of indoor $PM_{2.5}$ and PM_{10} concentrations compared with regions that have drier climate. Moreover, the predominance of wooden house, which are generally more permeable to air and particulate infiltration than permanent masonry structures, may further affect indoor air quality by facilitating the movement of outdoor pollutants into indoor environments. Consequently, the interaction between tropical climatic conditions and distinctive residential building characteristics provides a unique environmental setting and potential novelty for investigating indoor particulate pollution.

Addressing these research gaps is important for improving the understanding of how housing characteristics and the surrounding environment influence indoor particulate concentrations in tropical regions. Such evidence is essential for developing effective environmental health interventions and housing improvement strategies tailored to local conditions. Therefore, this study aimed to analyze the relationship between the physical characteristics of houses and their surrounding environment and indoor $PM_{2.5}$ and PM_{10} concentrations in the Sungai Pinang and Samarinda Ulu Districts of East Kalimantan, Indonesia. By simultaneously evaluating multiple housing and environmental factors in a humid tropical setting, this study provides new evidence on the determinants of indoor particulate pollution in a geographical context that remains underrepresented in the existing literature as an effort to identify potential public health risks.

2. Methods

This study was an analytical observational study using a cross-sectional design aimed at analyzing the relationship between determinants of housing conditions and indoor $PM_{2.5}$ and PM_{10} concentrations. The study was conducted from November to December 2025 in residential areas of Sungai Pinang District (Pelita and Sungai Pinang Dalam Subdistricts; Location 1) and Samarinda Ulu District (Bukit Pinang and Air Putih Subdistricts; Location 2), Samarinda City, East Kalimantan, Indonesia.



(a) (b)

Figure 1. Map of the Research Locations: Location 1 (a) and Location 2 (b)

The study population comprised all occupied houses located within a 250-meter radius of the main road. The sample consisted of 151 houses, determined using the Slovin formula and selected through purposive sampling based on inclusion criteria, including willingness to participate as respondents and being aged >17 years. The exclusion criteria were respondents (households) living in the same house, not residing at the selected areas, and unable to communicate properly.

The independent variables in this study included wall conditions, ventilation, ceilings, type of cooking fuel, occupancy density, and the presence of vegetation surrounding the house. The dependent variables were indoor $PM_{2.5}$ and PM_{10} concentrations. Housing characteristics were classified according to the Indonesian Ministry of Health Decree No. 829/1999 on Housing Health Requirements. Wall condition was categorized as permanent, semi-permanent, and non-permanent. Ventilation was classified as adequate (meeting the requirements) when the total ventilation area was at least 10% of the floor area and inadequate when it was less than 10%. Ceiling condition was categorized as adequate if the house had a clean, safe and well-maintained ceiling, whereas houses with dirty, damaged, unsafe or absent ceilings were categorized as inadequate. Occupancy density was categorized as adequate if the bedroom area was at least 4 m^2 per person aged over 10 years and inadequate when it was less than 4 m^2 per person. The presence of vegetation surrounding the house was assessed within a 5-meters radius of the building. Houses were categorized as having low environmental risk when vegetation (e.g. trees, ornamental plants, or potted plants) was present within this radius. Conversely, houses were classified as having high environmental risk when no vegetation was present within 5 meters of the building or when vegetation was located beyond this distance.

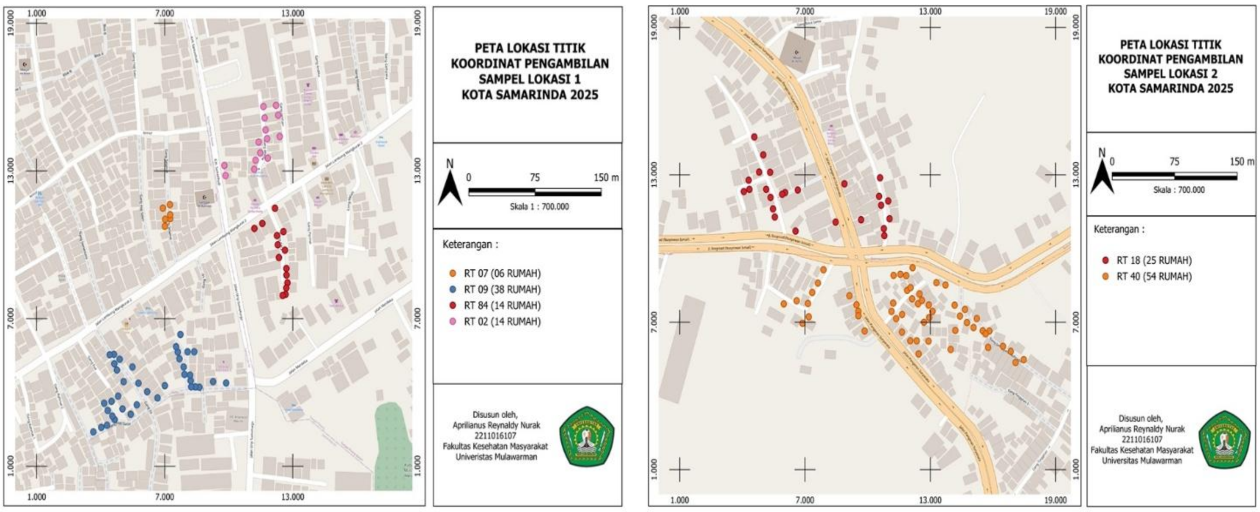
Indoor $PM_{2.5}$ and PM_{10} concentrations were measured using a Labtron Dust Detector employing a direct reading method equipped with integrated temperature and relative humidity sensors. Measurements were performed in the room most frequently used for family activities, with doors and windows closed during the measurement process. The instrument was positioned at a height of approximately 1.0–1.5 meters above the floor, representing the human breathing zone, at predetermined measurement points, and operated in accordance with the manufacturer's instructions. $PM_{2.5}$ and PM_{10} concentrations were expressed in μg/m^3, air temperature in °C, and relative humidity in %RH. All measurements were conducted during daytime between 11:00 AM–2:00 PM (Central Indonesian Time, UTC +8). Data were recorded after the instrument readings reached a stable condition. Measurements in each house were conducted twice to improve data reliability. All measurement results were recorded on observation sheets and used to calculate the average values of each parameter. The collected data were analyzed using IBM SPSS Statistics version 24. Descriptive (univariate) analysis was performed to summarize the characteristics of the study variables. Since $PM_{2.5}$ and PM_{10} data were not normally distributed, bivariate analysis were conducted using the Mann–Whitney and Kruskal–Wallis tests for variables with more than two categories. Statistical significance was established at a two-sided p-value of <0.05.

3. Results

3.1. Research area characteristics

Pelita and Sungai Pinang Dalam are Subdistricts located in Sungai Pinang District, Samarinda City, East Kalimantan, Indonesia. They cover areas of 892.07 ha and 897.80 ha respectively with populations of 14,007 and 38,192 inhabitants. The local economy is primarily supported by handicraft production, manufacturing, trade, and small-scale industries. Bukit Pinang and Air Putih are subdistricts located in Samarinda Ulu District, Samarinda City, covering areas of 19,687.50 ha and 200.14 ha respectively with populations of 12,266 and 23,264 inhabitants. Most residents in these areas are engaged in plantation, livestock, fisheries, and other urban economic activities (Pemkot, 2025).

The study site in Pelita and Sungai Pinang Dalam Subdistricts were located around the intersection of Lambung Mangkurat Street and comprised four neighborhood units (Rukun Tetangga, RT) situated within a 250-m radius of the intersection, namely RT 09, RT 07, RT 02, and RT 84. In Bukit Pinang and Air Putih Subdistricts, the study sites were located around the intersection of P. Suryanata Street and included two nearest neighborhood units within a 250-m radius, namely RT 40 and RT 18. These locations were selected because they represent densely populated residential area situated adjacent to major traffic corridors with relatively high vehicle activity. The residential environment is characterized by narrow alleys and houses with inadequate ventilation, resulting in limited indoor air circulation. Such housing and neighborhood characteristics may increase the penetration of outdoor air pollutants, including traffic-related particulate matter, into indoor environments. In addition, restricted air circulation within the house may reduce pollutant dispersion, potentially leading to elevated indoor particulate concentrations.



(a) (b)

Figure 2. Map of respondent distribution locations: Location 1 (a) and Location 2 (b)

3.2. $PM_{2.5}$ and PM_{10} concentrations

As shown in Table 1, measurement conducted in Location 1 (n = 72 houses), yielded a mean indoor $PM_{2.5}$ concentration of 9 μg/m^3 and a mean PM_{10} concentration of 52 μg/m^3. During the measurement the average indoor air temperature was 32.15°C with a relative humidity of 71% RH. Meanwhile, measurement in Location 2 (n = 79 houses) showed higher concentrations of both $PM_{2.5}$ (12 μg/m^3) and PM_{10} (71 μg/m^3), with a slightly higher air temperature (33.14°C)and relative humidity (72% RH).

Table 1. Distribution of $PM_{2.5}$ and PM_{10} concentrations

No	Location	Variable	*Mean*	Min-Max	SD (CI: 95%)	EQS (*)
1.	Location 1	$PM_{2.5}$ (μg/m^3)	9	1 - 56	8.714	25
		PM_{10} (μg/m^3)	52	15 - 174	30.672	70
		Temperature (°C)	32.15	29 - 35	1.456	18-30
		Humidity (%RH)	71	62 - 81	4.597	40-60
2.	Location 2	$PM_{2.5}$ (μg/m^3)	12	2 - 96	12.474	25
		PM_{10} (μg/m^3)	71	16 - 191	36.179	70
		Temperature (°C)	33.14	29 - 43	1.707	18-30
		Humidity (%RH)	72	66 - 83	3.504	40-60

** Environmental Quality Standard (EQS) Based on Minister of Health Regulation of the Republic of Indonesia No. 02 of 2023*

3.3. Houses Physical and Environmental Conditions

Table 2 shows the distribution of respondents' physical house characteristics. Among the 151 observed houses, most had non-permanent walls (72.8%), ventilation that did not meet health requirements (99.3%), and ceilings that met the requirements (51%). All houses used gas or LPG as cooking fuel type (100%). Most houses met the occupancy density requirements (68.9%), and the majority of houses had vegetation around the house within a distance of ≤5 meters (83.4%).).

Table 2. Univariate analysis results

No	Variable	Number (n=151)	Percentage (%)
1	Wall condition		
	Permanent	13	8.6
	Semi-permanent	28	18.5
	Non-permanent	110	72.8
2	Ventilation		
	Meets requirements	1	0.7
	Does not meet requirements	150	99.3
	Not available	0	0
3	Ceiling condition		
	Meets requirements	77	51
	Does not meet requirements	67	44.4
	Not available	7	4.6
4	Cooking fuel usage		
	Gas/LPG	151	100
	Electricity	0	0
	Kerosene	0	0
	Firewood	0	0
5	Occupancy density		
	Meets requirements	104	68.9
	Does not meet requirements	47	31.1
6	Presence of vegetation around the house		
	Non-risk	126	83.4
	Risk	25	16.6

3.4. The relationship between house conditions and $PM_{2.5}$ and PM_{10} concentrations

The results of the bivariate analysis are presented in Table 3. The house wall condition has a significant relationship with $PM_{2.5}$ concentration ($p = 0.040$) and PM_{10} concentration ($p = 0.049$). Meanwhile, ceiling conditions, ventilation, occupancy density, and the presence of vegetation around the house does not show significant relationships with either $PM_{2.5}$ or PM_{10} concentrations ($p > 0.05$).

Table 3. Analysis of the relationship between research variables and $PM_{2.5}$ and PM_{10} concentrations

No	Variable	*P value*	
		$PM_{2.5}$	PM_{10}
1.	Wall condition	0.040*	0.049*
2.	Ceiling condition	0.119	0.064
3.	Ventilation	0.463	0.324
4.	Occupancy density	0.875	0.743
5.	Presence of vegetation around the house	0.114	0.129

*Note: * Significant*

4. Discussion

The observed differences in indoor $PM_{2.5}$ and PM_{10} concentrations between the wo study locations were accompanied by slightly differences in indoor temperature and relative humidity. The location with relatively higher temperature showed slightly higher particulate concentrations, whereas higher humidity tended to be associated with lower particulate concentrations. Theoretically, temperature and humidity can influence particulate dynamics in the air, including surface drying processes that allow particles to become more easily dispersed and the role of humidity in particle deposition processes in the atmosphere (Anjelicha et al., 2022). In addition, the increasing air temperature is directly proportional to the increasing $PM_{2.5}$ and PM_{10} concentrations. High solar radiation intensity may trigger photochemical reactions in the atmosphere and generate secondary particles (Novichri et al., 2024). Differences in particulate concentrations between the two locations may also be influenced by surrounding environmental conditions that allow outdoor particles to enter indoor spaces through air infiltration and air exchange activities. Therefore, variations in $PM_{2.5}$ and PM_{10} concentrations not only reflect building physical conditions but also result from interactions between microclimatic conditions and the surrounding residential environment.

These external environmental conditions subsequently interact with the physical characteristics of residential buildings, particularly wall types. The classification of wall conditions refers to the Decree of the Minister of Health of the Republic of Indonesia No. 829 of 1999 concerning housing health requirements (Noviandari, 2021), where walls that meet health requirements are generally waterproof and dust-resistant. Conversely, wooden or board walls with poor construction tend to have gaps that facilitate the entry and accumulation of dust indoors (Meita et al., 2016). This condition is further supported by the characteristics of respondents' house ventilation, where almost all houses (99.3%) had ventilation that did not meet health requirements (less than 10% of the floor area). Only one house (0.7%) meets the requirements and no house without ventilation. Poor air exchange may increase the accumulation of indoor pollutants and microorganisms, potentially affecting negatively in occupants' health (Putra, 2024).

In addition to walls and ventilation, ceiling conditions also contribute to indoor air quality. The assessment showed that 77 houses (51%) met health requirements, while 67 houses (44.4%) did not meet the requirements, and 7 houses (4.6%) did not have ceilings. Dirty, damaged, or difficult-to-clean ceilings may increase the risk of respiratory disorders due to exposure to dust containing bacteria or viruses that cause acute respiratory infections (Sartika, 2022). Furthermore, all respondent houses (100%) used gas or LPG as cooking fuel, consistent with the government policy of converting kerosene to LPG to provide cleaner and more efficient household energy sources (Pranadji et al., 2017).

Regarding occupancy density, most respondent houses met the minimum housing area requirements, with 104 houses (68.9%) having an area of ≥ 4 m² per person, while 47 houses (31.1%) were categorized as overcrowded. High occupancy density may increase indoor CO_2 levels, reduce air quality, and contribute to decreased occupants' immunity (Budi et al., 2024). Moreover, vegetation around houses was observed in 126 houses (83.4%), while 25 houses (16.6%) had no vegetation or vegetation located more than 5 meters away. Vegetation is known to contribute in reducing dust and air pollutants through the ability of leaves to capture particulate matter and improve the quality of residential environments (Gustin et al., 2024).

Statistical analysis showed that house wall conditions were significantly associated with $PM_{2.5}$ and PM_{10} concentrations. This finding is consistent with previous studies reporting an association between house wall conditions and the incidence of acute respiratory infections (Putri, P. D., & Mantu, M. R., 2019; Titi & Intan, 2021). Permanent walls made of concrete or plastered bricks are more resistant to dust infiltration, easier to clean, and more durable against weather exposure, thereby reducing the entry of pollutants into indoor environments. In contrast, non-permanent or semi-permanent walls tend to be porous and have gaps that facilitate the infiltration of dust and air pollutants (Akbar et al., 2021; Hariningsih et al., 2023; Romauli et al., 2021; Susanto, 2021). However, permanent walls may still become a medium for pathogen growth if cleanliness is not maintained (Wulandhani & Purnamasari, 2019).

Although ventilation, ceiling conditions, occupancy density, and vegetation around houses theoretically have the potential to influence indoor air quality, this study found no significant association between these variables and $PM_{2.5}$ and PM_{10} concentrations. This finding may be related to the relatively homogeneous distribution of research data. Based on Table 2, most respondents were in the same category for several variables, particularly ventilation, where almost all houses did not meet health requirements. Limited data variation may reduce differences between groups, thereby decreasing the ability of statistical analysis to detect significant associations. In contrast, wall condition varies across categories, allowing its association with $PM_{2.5}$ and PM_{10} concentrations to be statistically identified.

The absence of a significant relationship between ceiling conditions and $PM_{2.5}$ and PM_{10} concentrations indicates that the presence of ceilings alone may not be sufficient to reduce indoor particulate concentrations. This finding is consistent with previous studies stating that damaged or difficult-to-clean ceilings can become locations for dust accumulation that may be resuspended into indoor air (Anwar & Dharmayanti, 2014; Dewiningsih, 2018; Nalasari & Pertiwi, 2019). Ventilation and occupancy density also showed no significant association with $PM_{2.5}$ and PM_{10} concentrations. This suggests that the effects of these variables on indoor air quality may be influenced by interactions with other factors, such as temperature, humidity, and pollutant sources from indoor and outdoor environments (Manese et al., 2016; Zairinayati & Putri, 2020).

The presence of vegetation around houses also showed no significant association with $PM_{2.5}$ and PM_{10} concentrations. This condition may be due to the effectiveness of vegetation in reducing air pollutants depending on plant species, leaf structure and surface area, as well as canopy density. Furthermore, this study only assessed the presence and distance of vegetation from houses and did not measure the actual capacity of vegetation to absorb particulate matter. Therefore, the presence of vegetation alone may not necessarily produce a measurable reduction in particulate concentrations in residential areas (Azzahro et al., 2019; Syahadat et al., 2020).

The findings of this study should be interpreted considering several limitations. The relatively homogeneous distribution of data in most variables resulted in limited variation between groups, which may affect the ability of statistical analysis to detect significant associations. In addition, this study did not consider external environmental factors that may influence indoor $PM_{2.5}$ and PM_{10} concentrations. Differences in surrounding environmental conditions between locations may also contribute to variations in measured particulate concentrations. Therefore, future studies should consider external environmental factors and use samples with more diverse characteristics to provide a more comprehensive analysis of indoor air quality determinants.

5. Conclusions

This study demonstrates that the characteristic of house wall is associated with $PM_{2.5}$ and PM_{10} concentrations in residential areas of Sungai Pinang and Samarinda Ulu Districts. Meanwhile, ventilation conditions, ceilings, occupancy density, and the presence of surrounding vegetation did not show significant associations. These findings indicate that building physical characteristics, particularly wall conditions, play an important role in influencing indoor air quality. Efforts to improve indoor air quality can be implemented through the use of denser wall materials with minimal gaps to reduce the infiltration of particulate matter from outdoor environments. Proper management of household ventilation should also be maintained by ensuring ventilation cleanliness and optimizing air circulation regularly. Planting vegetation around houses with dust-absorbing capabilities may serve as a supporting measure to maintain environmental air quality. Further research is recommended to investigate the relationship between physical housing conditions, indoor air quality, and the occurrence of respiratory health problems, as well as to conduct Environmental Health Risk Assessment to estimate potential public health risks associated with long-term exposure to particulate matter.

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