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Indoor Air Quality Assessment in Port Office Facilities: A Case Study of PT X

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Abstract

Purpose: This study aimed to evaluate the indoor air quality (IAQ) in the office areas of PT X based on physical, chemical, and biological parameters and to assess compliance with the Threshold Limit Values (TLVs) specified in the Indonesian Minister of Manpower Regulation No. 5 of 2018.

Methods: A quantitative descriptive approach was used. Indoor air quality was measured in six office rooms using standardized instruments by an accredited testing laboratory, supported by field observations and interviews with employees.

Results: All measured chemical parameters (HCHO, CO_2, CO, NO_2, O_3, PM_{10}, and TVOC) and biological parameters (total airborne bacteria and fungi) in the six office rooms were below the applicable TLVs. Among the physical parameters, the relative humidity and air velocity complied with the prescribed standards at all locations. However, the indoor temperature in four of the six rooms (66.7%) exceeded the recommended threshold of 25.5°C.

Conclusion: Overall, the indoor air quality at PT X was considered satisfactory and safe for employees. Nevertheless, thermal comfort remains a concern, as indoor temperatures exceeded the recommended standard in most of the rooms evaluated.

Limitations: This study was limited to six non-production office rooms and a single measurement period, limiting its ability to capture seasonal variations, work shift differences, and conditions in operational or production areas.

Contribution: This study provides baseline data and practical recommendations for improving HVAC management and enriches the limited evidence on indoor air quality in Indonesia's ports.

Keywords: *Biological Parameters, Chemical Parameters, Indoor Air Quality, Occupational Health, Physical Parameters.*

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1. Introduction

Indoor air quality (IAQ) is an important determinant of human health, comfort, and productivity, considering that most modern human activities occur in enclosed indoor environments (Deng, Dong, Guo, & Zhang, 2024; Mewomo, Toyin, Iyiola, & Aluko, 2023). Poor IAQ conditions may result from the accumulation of chemical pollutants, particulate matter, and biological contaminants, as well as inadequate ventilation and improper thermal conditions. The World Health Organization (WHO) states that indoor air pollution occurs when harmful substances, such as fine particulate matter, toxic gases, or microorganisms, accumulate in enclosed spaces at concentrations that exceed safe limits. This condition has been shown to contribute to a variety of health problems, ranging from respiratory tract irritation to cardiovascular disease (Ali, Lin, Yousaf, Abbas, Munir, Rashid, & Wong, 2022; Raju, Siddharthan, & McCormack, 2020; Maung, Bishop, Holt, Turner, & Pfrang, 2022).

In Indonesia, increasing attention has been paid to indoor air quality, as office and industrial workers spend more of their working hours inside buildings (Amriyati, 2022). This growing concern is driven by the recognition that indoor environmental conditions directly influence occupational health, employee comfort, and work productivity. The government has established several regulations to protect workers' health, including Minister of Health Regulation No. 1077 of 2011 and Minister of Manpower Regulation No. 5 of 2018 concerning Occupational Safety and Health in the Work Environment, which stipulate the Threshold Limit Values (TLVs) for physical, chemical, and biological parameters of indoor air in office environments. Compliance with these regulations is an obligation for every company to ensure a healthy and safe working environment for its employees. These regulations emphasize the importance of controlling physical, chemical, and biological factors to ensure a healthy and safe working environment (Gola, Settimo, & Capolongo, 2019).

The port sector is one of the industries characterized by highly intensive logistics activities, including cargo loading and unloading operations, heavy equipment movements, and vehicle traffic (Sarkar, Shankar, & Kar, 2023; Haralambides, 2019), all of which have the potential to generate exhaust emissions and airborne dust in the surrounding environment (Kelly, & Fussell, 2020; Rouhani, Iqbal, Roman, & Hejcman, 2025). These conditions raise questions regarding the extent to which such operational activities affect the air quality of office spaces adjacent to operational areas. PT X, as a multipurpose terminal operator, represents a typical port working environment with these characteristics, making it a relevant case for further investigation.

To date, empirical studies on indoor air quality in Indonesia's port sector remain relatively limited compared to those conducted in general office buildings, hospitals, or educational institutions. Based on this research gap, the present study aims to evaluate the indoor air quality conditions at PT X based on physical, chemical, and biological parameters and assess their compliance with the Indonesian Minister of Manpower Regulation No. 5 of 2018. The findings are expected to provide an overview of the existing indoor air quality conditions, while serving as a basis for developing appropriate and targeted improvement recommendations.

2. Literature Review and Hypothesis/es Development

2.1 Air

Air is a mixture of gases in the Earth's atmosphere, consisting of approximately 78% nitrogen, 21% oxygen, 0.93% argon, and small amounts of other gases, such as carbon dioxide and water vapor Schlesinger & Bernhardt, 2020. It serves as a medium for the respiration of living organisms and influences weather and climate through various physical processes. Air quality is defined as the condition or level of air purity in a particular area, which is influenced by the composition of gases (Fowler et al., 2020; Manisalidis et al., 2020), concentration of pollutants, and airborne particulate matter that affect both human health and ecosystems (Nyayapathi et al., 2025; Lang et al., 2025).

Air quality is generally classified into ambient and indoor air quality. Indoor air quality is a particularly important aspect of the workplace because most employees spend up to eight hours or more each day inside buildings (Tran et al., 2020; Zhang & Srinivasan, 2020). The deterioration of indoor air quality may result from various factors, including inadequate ventilation, high occupant density, operational activities, use of electronic equipment, building materials, furniture, and infiltration of pollutants from outdoor environments. These conditions can increase the concentration of physical, chemical, and biological pollutants, which may lead to health problems such as irritation of the eyes, nose, and throat, headaches, respiratory disorders, reduced concentration, and Sick Building Syndrome (SBS) Shetty et al., 2023. Therefore, regular monitoring and control of indoor air quality are necessary to ensure that the workplace remains healthy, safe, and comfortable for all occupants.

2.2 Air Pollution

Air pollution is one of the major environmental issues that affects human health, ecosystems, and overall environmental quality. It refers to the presence of pollutants in the atmosphere in the form of gases, particulate matter, or biological substances at concentrations that may cause harmful effects. Government Regulation No. 41 of 1999 defines air pollution as the introduction of substances or energy into ambient air as a result of human activities, causing air quality to no longer fulfill its intended function (Government, 1999). Air pollution may originate from natural sources, such as volcanic eruptions, and anthropogenic sources, such as transportation and industrial emissions. Air pollution in enclosed spaces, such as houses, schools, and offices, is referred to as indoor air pollution (Karri, Vera, Hassan, Khoder, Dehghani, Mubarak, & Ravindran, 2024).

he composition and concentration of air pollutants vary depending on emission sources, environmental conditions, and pollutant dispersion mechanisms. Common air pollutants include particulate matter (PM_{10} and $PM_{2.5}$), carbon monoxide (CO), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), ozone (O_3), and volatile organic compounds (VOCs). These pollutants may have adverse impacts on human health, particularly through respiratory and cardiovascular pathways. Long-term exposure to polluted air has been associated with increased risks of respiratory diseases, reduced lung function, and other chronic health problems. Therefore, controlling air pollution has become an important aspect of environmental protection and public health management (Alam, Karim, & Zaman, 2025).

In addition to outdoor air pollution, pollutants can also accumulate in enclosed environments, resulting in indoor air pollution. Indoor air pollution occurs when various pollutants accumulate inside a building to concentrations that exceed those considered safe for human health. Pollutants may originate from indoor sources, including building materials, furniture, cleaning products, cigarette smoke, occupant activities, use of electronic equipment, and poorly maintained ventilation or air conditioning systems. In addition, outdoor pollutants may enter buildings through ventilation systems, doors, and windows, particularly in buildings located in areas with heavy traffic or industrial activities (Alqahtani et al., 2025; Islam, 2025). Continuous exposure to indoor air pollutants can result in a variety of adverse health effects, including irritation of the eyes, nose, and throat, respiratory disorders, allergic reactions, and reduced work productivity. Therefore, managing indoor air quality through source control, providing adequate ventilation, and regular air quality monitoring is essential for creating a healthy and safe environment for building occupants (De Capua et al., 2023; Winck et al., 2022).

2.3 Indoor Air Quality

Indoor air quality (IAQ) refers to the physical, chemical, and biological conditions of the air inside a building that affect the health, comfort, and productivity of its occupants. The concentration of indoor pollutants can be two to five times higher than that of outdoor air, particularly in buildings with inadequate ventilation. Indoor sources of pollutants include cigarette smoke, cooking activities, chemical cleaning products, paints, furniture coatings, and building materials that emit volatile organic compounds (VOCs) (Dimitroulopoulou, Dudzińska, Gunnarsen, Hägerhed, Maula, Singh, & Haverinen-Shaughnessy, 2023; Deng, Dong, Guo, & Zhang, 2024).

In addition to these pollution sources, indoor air quality is influenced by ventilation conditions, occupant density, indoor activities, and the maintenance of ventilation and air conditioning systems. Inadequate ventilation can lead to the accumulation of various pollutants, such as carbon dioxide

(CO_2), particulate matter (PM_{10}), formaldehyde (HCHO), total volatile organic compounds (TVOC), and microorganisms such as bacteria and fungi (Malakan, Kc, Jalearnkittiwut, & Samniang, 2025). These conditions can reduce indoor air quality and increase the risk of adverse health effects in occupants. The resulting health effects include eye, nose, and throat irritation, headaches, fatigue, reduced concentration, allergic reactions, and respiratory disorders. Therefore, indoor air quality should be monitored regularly by measuring physical, chemical, and biological parameters, supported by proper ventilation management and good environmental hygiene practices to create a healthy, safe, and comfortable working environment (Tran, Park, & Lee, 2020).

2.4 Indoor Air Quality in Office Buildings

Indoor Air Quality (IAQ) refers to the condition of air within buildings and its impact on the health, comfort, and productivity of occupants. Office buildings are among the most important environments for IAQ assessment because employees typically spend a substantial portion of their daily activities indoors (Deng, Dong, Guo, & Zhang, 2024). Poor IAQ conditions may arise from various factors, including inadequate ventilation, accumulation of indoor pollutants, emissions from building materials and office equipment, occupant activities, and biological contamination. These factors may contribute to discomfort, respiratory symptoms, reduced work performance, and increased health risks among building occupants (Tran, Park, & Lee, 2020; Malakan, Kc, Jalearnkittiwut, & Samniang, 2025).

Maintaining good IAQ in office buildings requires an integrated approach involving effective ventilation management, proper operation of HVAC systems, regular maintenance, and control of pollutant sources (Tejani & Khandelwal, 2023). Adequate indoor air conditions not only reduce exposure to harmful contaminants but also support thermal comfort, employee well-being, and workplace productivity. Therefore, IAQ assessment based on comprehensive measurements of physical, chemical, and biological parameters is essential to evaluate workplace environmental conditions and ensure compliance with applicable health and safety standards.

2.5 Indoor Air Quality Parameters

In Indonesia, indoor air quality standards are regulated by Ministry (2011) and Ministry (2018). These regulations establish Threshold Limit Values (TLVs) for physical, chemical, and biological parameters to protect workers' health and serve as references for routine indoor air quality monitoring in the workplace. The implementation of these standards aims to prevent health problems resulting from exposure to indoor air pollutants while creating a safe, healthy, and comfortable working environment for employees. Indoor air quality monitoring is carried out by measuring various physical parameters, such as temperature, relative humidity, and air velocity; chemical parameters, including carbon dioxide (CO_2), carbon monoxide (CO), formaldehyde (HCHO), nitrogen dioxide (NO_2), ozone (O_3), particulate matter (PM_{10}), and total volatile organic compounds (TVOC); and biological parameters, such as airborne bacterial and fungal counts (Saini, Dutta, & Marques, 2020). The measurement results were then compared with the established Threshold Limit Values (TLVs) to determine whether the indoor air quality complied with occupational environmental health standards (Saffell & Nehr, 2023). This evaluation serves as the basis for developing control measures, such as improving ventilation systems, maintaining building facilities, and reducing pollution sources, thereby minimizing the risk of adverse health effects in workers.

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Indoor air quality (IAQ) parameters are classified into three categories: physical, chemical, and biological parameters, as stipulated in the Ministry (2018).

Table 1. Threshold Limit Value (TLV) for Indoor Air Quality according to Minister of Manpower Regulation No. 05 of 2018

Group	Test Parameters	NAB	Unit
Physics	Relative Humidity	< 70	%RH
	Air Movement/Flow Rate	< 0,3	m/s
	Room Temperature	< 25,5	°C
Chemistry	Formaldehyde (HCHO)	< 100	µg/m³
	Carbon Dioxide (CO2)	< 1.000	ppm
	Carbon Monoxide (CO)	< 10.000	µg/m³
	Nitrogen Dioxide (NO2)	< 150	µg/m³
	Ozone (O3)	< 120	ppm
	Particulate Matter (PM10)	< 180	µg/m³
	Total VOCs (TVOC)	< 600	µg/m³
Biology	Total Bacterial Count	500	CFU/m³
	Total Fungal Count	1.000	CFU/m³

Based on Table 1, Ministry (2018) specifies that the physical parameters include temperature, relative humidity, and air velocity. Excessively high humidity promotes the growth of microorganisms, whereas excessively low humidity causes dryness and discomfort among workers. An optimal indoor temperature supports workers' thermal comfort, whereas adequate air velocity plays an important role in preventing the accumulation of pollutants in poorly ventilated spaces (Ratajczak, Amanowicz, Pałaszyńska, Pawlak, & Sinacka, 2023).

The chemical parameters included gases and airborne pollutants, such as formaldehyde (HCHO), carbon dioxide (CO_2), carbon monoxide (CO), nitrogen dioxide (NO_2), ozone (O_3), particulate matter (PM_{10}), and total volatile organic compounds (TVOC). Each of these pollutants has distinct characteristics and poses different health risks, ranging from mild irritation to severe toxicity at high concentrations. The biological parameters included the presence of airborne bacteria and fungi, which were measured in colony-forming units per cubic meter (CFU/m³). Microbial concentrations exceeding Threshold Limit Values (TLVs) may increase the risk of allergic reactions, respiratory tract infections, and reduced workplace comfort (Nwakoby, Iheukwumere, Iheukwumere, Nwakoby, Idigo, & Ike, 2025).

2.6 Indoor Air Quality Control Measures

Indoor air pollution can be controlled using several strategies, including controlling pollution sources at their origin, diluting and removing pollutants through adequate ventilation systems (either natural or mechanical), and using air filtration devices Kumar et al., 2023. Commonly used equipment to maintain indoor air quality includes air purifiers, air humidifiers, exhaust fans, and air conditioners (ACs), each serving a specific function in filtering, humidifying, circulating, or cooling indoor air Tahir Bahaur et al., 2025.

The effectiveness of indoor air quality control depends not only on the use of such equipment but also on comprehensive environmental management Mata et al., 2022. Routine maintenance of ventilation and air conditioning systems, regular filter cleaning, humidity control, and implementation of good workplace housekeeping practices are essential measures to prevent the accumulation of pollutants and the growth of microorganisms. In addition, indoor air quality should be monitored regularly to ensure that all physical, chemical, and biological parameters remain below the established Threshold Limit Values (TLVs). Through the implementation of comprehensive control measures, the risk of adverse health effects resulting from exposure to indoor air pollutants can be minimized, thereby creating a healthy, safe, comfortable, and productive working environment for building occupants (Tran et al., 2020; Kumar et al., 2023).

3. Research Methodology

3.1 Research Design

This study employed a quantitative descriptive research design to evaluate the indoor air quality (IAQ) conditions in office facilities at PT X. This study aimed to describe the existing indoor environmental conditions based on physical, chemical, and biological parameters and assess their compliance with the Threshold Limit Values (TLVs) stipulated in the Indonesian Minister of Manpower Regulation No. 5 of 2018. The quantitative approach was applied because the assessment was based on numerical measurement results obtained through direct indoor air quality monitoring and compared with the applicable regulatory standards (Basil et al., 2024; Zhang & Srinivasan, 2020).

3.2 Research Location and Measurement Area

The research was conducted in the office facilities of PT X. The measurement areas consisted of six non-production office rooms that represented different workplace functions. The selected rooms included managerial, operational support, financial, technical, and administrative workspaces. These locations were selected to represent the indoor working conditions experienced by employees and to provide an overview of the indoor air quality conditions within the office environment.

3.3 Data Collection and Measurement Procedure

Indoor air quality measurements were conducted by an accredited testing laboratory (hereinafter referred to as Laboratory Y) using standardized instruments. The assessment covered three categories of indoor air quality parameters: physical, chemical, and biological. The physical parameters included room temperature, relative humidity (RH), and air velocity. The chemical parameters included formaldehyde (HCHO), carbon dioxide (CO_2), carbon monoxide (CO), nitrogen dioxide (NO_2), ozone (O_3), particulate matter (PM_{10}), and total volatile organic compounds (TVOC). The biological parameters included the total airborne bacterial and fungal counts measured in colony-forming units per cubic meter (CFU/m^3). Field observations and interviews were conducted to obtain supporting information regarding workplace conditions, ventilation systems, and potential factors influencing indoor air quality.

3.4 Data Analysis

The measurement results were analyzed using descriptive analysis by comparing the obtained values with the Threshold Limit Values (TLVs) established in the Indonesian Minister of Manpower Regulation No. 5 of 2018. Each parameter was evaluated and categorized as meeting or not meeting the required standards. Analysis focused on identifying indoor air quality conditions, potential pollutant sources, ventilation effectiveness, and thermal comfort. The results were then used as a basis for evaluating the overall indoor air quality and developing recommendations for improving workplace environmental conditions.

4. Results and Discussions

4.1 Results

Indoor air quality measurements were conducted in six office rooms at PT X by a certified testing laboratory (hereinafter referred to as Laboratory Y), covering physical, chemical, and biological parameters.

4.1.1 Results of Physical Parameter Measurements

Table 2. Results of Physical Parameter Measurements

Location	Temperature (°C) <25,5	RH (%) <70	Flow Rate (m/s) <0,3	Interpretation
Branch Manager Room	24,0	53,0	0,189	Complies
Deputy Operations & Engineering Room	26,0	53,0	0,253	Does Not Comply (Temperature)
Deputy Operations Support Room	25,0	54,0	0,183	Complies
Finance Supervisor Room	25,9	53,0	0,243	Does Not Comply (Temperature)
First Floor Workspace	26,0	48,0	0,175	Does Not Comply (Temperature)
Engineering & HSSE Room	26,1	54,0	0,237	Does Not Comply (Temperature)

Table 2 shows that the physical parameter measurements indicate that the relative humidity (RH) in all workspaces ranged from 48% to 54%, which remains within the permissible threshold of <70%. Similarly, the air velocity ranged from 0.175 to 0.253 m/s, with all measurements below the maximum limit of 0.3 m/s. However, the temperature did not comply with the required standard. Among the six measured locations, only the Branch Manager Room (24.0°C) and the Deputy Operations Support Room (25.0°C) met the temperature requirement (<25.5°C). Meanwhile, the Deputy Operations & Engineering Room (26.0°C), Finance Supervisor Room (25.9°C), First Floor Workspace (26.0°C), and Engineering & HSSE Room (26.1°C) recorded temperatures exceeding the threshold value, indicating that these locations did not meet the specified requirements for temperature.

4.1.2 Results of Chemical Parameter Measurements

Table 3. Results of Chemical Parameter Measurements

Location	HCHO (µg/m³)	CO2 (ppm)	CO (µg/m³)	NO2 (µg/m³)	O3 (ppm)	PM10 (µg/m³)	TVOC (µg/m³)	Interp.
Branch Manager Room	34	606	<1.143	<15,57	<5,51	27	126	M
Deputy Operations & Engineering Room	47	675	<1.143	<15,57	<5,51	37	64	M
Deputy Operations Support Room	34	664	<1.143	<15,57	<5,51	30	102	M
Finance Supervisor Room	31	735	<1.143	<15,57	<5,51	36	115	M
First Floor Workspace	28	732	<1.143	<15,57	<5,51	42	124	M
Engineering & HSSE Room	32	463	<1.143	<15,57	<5,51	32	139	M

Note: M = Meets the Threshold Limit Value (TLV).

Based on Table 3, the results of the chemical parameter measurements indicate that all workspaces complied with the indoor air quality requirements. The formaldehyde (HCHO) concentrations ranged from 28–47 µg/m³, carbon dioxide (CO_2) levels ranged from 463–735 ppm, particulate matter PM_{10}

concentrations ranged from 27–42 µg/m³, and total volatile organic compounds (TVOC) levels ranged from 64–139 µg/m³. The concentrations of carbon monoxide (CO), nitrogen dioxide (NO_2), and ozone (O_3) at all measurement locations were below the instrument detection limits, indicating very low levels. Overall, all measured chemical parameters were below the specified threshold values, indicating that the indoor air quality at the six measurement locations met the required standards.

4.1.3 Results of Biological Parameter Measurements

Table 4. Results of Biological Parameter Measurements

Location	Bacteria (CFU/m³) <500	Fungi (CFU/m³) <1.000	Interpretation
Branch Manager Room	38	6	Complies
Deputy Operations & Engineering Room	25	6	Complies
Deputy Operations Support Room	69	4	Complies
Finance Supervisor Room	58	7	Complies
First Floor Workspace	53	11	Complies
Engineering & HSSE Room	84	13	Complies

Based on Table 4, the results of the biological parameter measurements indicate that all workspaces complied with the indoor air quality requirements. The airborne bacterial concentrations ranged from 25–84 CFU/m³, whereas fungal concentrations ranged from 4–13 CFU/m³. All measurement results were considerably below the specified threshold values, namely, <500 CFU/m³ for bacteria and <1,000 CFU/m³ for fungi. Therefore, the biological air conditions at the six measurement locations can be categorized as meeting the required standards, indicating a low level of microorganism contamination in the workplace environment.

4.2 Discussion

The physical parameter measurement results indicated that the relative humidity in all rooms ranged from 48% to 54%, which is considerably below the threshold value of 70%. This suggests that the indoor air environment is unlikely to promote microorganism growth or cause excessive dryness discomfort among workers. The air velocity also remained within the acceptable range of 0.175–0.253 m/s, indicating relatively adequate air circulation, although several rooms approached the maximum limit of 0.3 m/s. The main concern identified was room temperature: among the six measured rooms, only the Branch Manager Room (24.0°C) and the Deputy Operations Support Room (25.0°C) met the required standard, while the other four rooms recorded temperatures ranging from 25.9–26.1°C, exceeding the threshold of 25.5°C. This temperature non-compliance in most rooms indicates potential issues with air conditioning system performance or uncontrolled internal heat loads, which may reduce thermal comfort and work productivity, although it may not necessarily result in immediate health risks to the occupants.

For chemical parameters, all measured compounds—including HCHO (28–47 µg/m³), CO_2 (463–735 ppm), CO, NO_2, and O_3 (below the instrument detection limits), PM_{10} (27–42 µg/m³), and TVOC (64–139 µg/m³)—were well below the established threshold values. The relatively low CO_2 concentrations indicated that air exchange within the rooms was functioning adequately, preventing significant accumulation of respiratory gases and combustion-related pollutants. The low levels of TVOC and PM_{10} also suggest minimal emissions from building materials, furniture, or office activities, despite the office locations being situated within a port environment characterized by intensive loading and unloading activities and heavy-vehicle traffic.

The biological parameters also demonstrated safe conditions, with bacterial concentrations ranging from 25–84 CFU/m³ and fungal concentrations from 4–13 CFU/m³, both far below the permissible limits of 500 and 1, 000 CFU/m ³ for bacteria and fungi, respectively. The highest biological concentrations were observed in the Engineering and HSSE Rooms; however, the values remained within the safe category. These findings reflect adequate room cleanliness management and ventilation system performance in controlling microorganism growth in the workplace environment Gola et al., 2019.

These findings demonstrate a consistent pattern: parameters related to chemical and biological contamination were well controlled, whereas the main issue was associated with thermal comfort conditions. This pattern is important to emphasize, as it indicates that internal pollutant sources from building materials, workplace activities, and microorganisms have been effectively managed Rabajczyk et al., 2021. However, further optimization of air conditioning (AC) system performance and internal heat load management is still required to achieve comprehensive workplace comfort for office employees in the port environment Ismail & Ouahrani, 2023. These improvements align with the principles of indoor air quality control through the optimization of ventilation and air-conditioning systems.

5. Conclusions

Based on the evaluation of indoor air quality at PT X, it can be concluded that the indoor air quality conditions across the six investigated office rooms were generally categorized as safe for worker health. All chemical parameters (HCHO, CO_2, CO, NO_2, O_3, PM_{10}, and TVOC) and biological parameters (bacteria and fungi) complied with the permissible threshold values stipulated in Minister of Manpower Regulation No. 5 of 2018, as did the physical parameters of relative humidity and air velocity. However, temperature-related issues were identified, with four of the six rooms (66.7%) exceeding the maximum threshold of 25.5°C. This condition may reduce thermal comfort and work productivity, although it does not result in significant chemical or biological pollution risks. These findings indicate that internal pollutant control measures within the company have been effectively implemented, although further optimization of air conditioning systems and air circulation management is still required to establish a more comprehensive and optimal workplace environment.

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Author Contributions

I.A. contributed to conceptualization, methodology, data collection, data analysis, interpretation of results, and manuscript preparation. N. contributed to the validation, review, and revision of this manuscript. Both authors reviewed and approved the final manuscript for publication.

Conflict of Interest

The authors declare no conflicts of interest regarding the publication of this article. The research was conducted independently, and there were no financial, personal, or professional relationships that could have influenced the research process, analysis, or interpretation of the findings.

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