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(Review Article)

Assessing the impact of natural ventilation on indoor air quality in residential buildings: A Case Study in Dhaka

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Abstract

This research investigates the impact of natural ventilation on indoor air quality (IAQ) in residential buildings in Dhaka, focusing on the concentration of formaldehyde (HCHO) and volatile organic compounds (VOCs), particularly toluene. Utilizing an experimental-comparative approach, the study measures IAQ under two ventilation conditions: "Natural Ventilation OPEN" (windows, balcony doors, and exhaust systems operational) and "Natural Ventilation CLOSE" (sealed indoor environment). Data was collected across 12 sessions over three months (May to July 2024), using IAQ Process Test Methods prescribed by the World Health Organization (WHO). Measurements included temperature, humidity, formaldehyde, and toluene concentrations in living rooms and adjacent balconies. Results revealed that natural ventilation significantly improved IAQ, with pollutant concentrations reduced by approximately 40% during the summer months. However, variations in ventilation rates (0.3–0.8 times/h) did not significantly affect IAQ, suggesting that external environmental factors, such as outdoor air quality and seasonal changes, played a more critical role. The study also analyzed the effects of different ventilation configurations, including supply/exhaust duct systems and heat exchanger types. While all systems demonstrated moderate improvements in IAQ, natural ventilation was the most effective in reducing pollutant levels, particularly formaldehyde and toluene. This research highlights the importance of natural ventilation in mitigating indoor air pollution in Dhaka's tropical climate. However, unexpected spikes in pollutant levels and minimal differences across ventilation systems suggest the need for further investigation into alternative strategies, building materials, and environmental conditions to optimize IAQ. These findings provide valuable guidance for architects, policymakers, and residents in designing healthier, energy-efficient residential buildings while addressing IAQ challenges in urban settings

Keywords: Indoor air quality (IAQ); Formaldehyde (HCHO); Volatile organic compounds (VOCs); Natural ventilation; Residential building

1. Introduction

Designers and architects face the challenge of creating and maintaining a safe and healthy indoor environment, considering that most people spend about 90% of their time indoors, where pollutant concentrations can be 2 to 5 times worse than outdoor air, according to the US EPA. IAQ is a critical environmental issue because indoor air pollution can cause various health problems, including respiratory issues, headaches, and even an increased risk of cancer (Batterman et al., 2012a; Verriele et al., 2016; Zorpas and Skouroupatis, 2016. Pollutants tend to accumulate in indoor environments due to poor air circulation and multiple pollution sources, with formaldehyde and volatile organic compounds (VOCs) being particularly harmful (Gong et al., 2017; Pei et al., 2013). Formaldehyde and VOCs are linked to non-cancer effects

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like asthma and liver poisoning, as well as cancer risks (Rumchev et al., 2007; Dai et al., 2017; WHO, 2000). Building materials and furniture are primary sources of these pollutants (Zhang et al., 2016; Cheng et al., 2017).

Recent studies highlight that newly decorated homes have higher formaldehyde and VOC concentrations, indicating a need for research into their emission characteristics (Park and Ikeda, 2006; Chi et al., 2016). The World Health Organization (WHO) defines Sick Building Syndrome (SBS), which includes symptoms like eye, nose, and throat irritation, headaches, and fatigue, all of which are linked to poor ventilation, dampness, and the presence of VOCs (Apter et al., 1994; WHO, 1983; Sahlberg et al., 2010). Studies have shown that exposure to VOCs at concentrations as low as 25 mg/m^3 can cause symptoms like eye irritation and headaches (Hudnell et al., 1992; Cometto-Muniz and Abraham, 2015).

Furthermore improving IAQ is crucial for preventing exposure to contaminated indoor air and ensuring a healthy living environment, aligning with global health goals such as the United Nations Sustainable Development Goals (SDGs) on health and well-being (Goal 3) and sustainable cities (Goal 11) (Feichtinger, 2020; Ouled-Diaf et al., 2022). In Dubai, IAQ awareness has increased due to public health concerns, stricter environmental regulations, and government initiatives (Jung and Awad, 2021a; Awad and Jung, 2021; Jung et al., 2021a). The Dubai Municipality has implemented IAQ standards for both residential and commercial buildings, covering ventilation, material choice, and testing protocols (Jung and Awad, 2021b; Mahmoud et al., 2023a). Dubai has also adopted green building standards to improve IAQ through sustainable construction practices (Arar et al., 2021; Jung et al., 2022d).

Moreover in Dhaka, IAQ levels are particularly concerning, with the highest concentrations of PM2.5 and PM10 globally, leading to significant health risks (Kumar et al., 2022). A study in the city found elevated levels of indoor pollutants, such as CO2, formaldehyde, and CO, in a large percentage of residences (Nahar et al., 2016). Pollutants like SO2, NO2, PM2.5, and VOCs are linked to health issues including heart disease, pneumonia, and respiratory diseases (Heal et al., 2012; Dherani et al., 2008). Despite this, Bangladesh lacks a formal standard for IAQ, which highlights the need for effective regulations and policies to address these issues (The Daily Star, June 4, 2022).

However this study,explore the emission behavior of formaldehyde and other VOCs from building materials such as particleboard, focusing on how ventilation and temperature affect emissions. Understanding these emission characteristics is essential for mitigating indoor air pollution and improving IAQ in residential buildings (Feichtinger, 2020; Ouled-Diaf et al., 2022). The World Health Organization (2010) outlines permissible indoor air concentration limits for pollutants, emphasizing formaldehyde levels at 0.1 mg/m^3 over 30 minutes and a weekly average of 260 μg/m^3 for toluene. This study also analyzes the ventilation systems' operational impact on IAQ, supported by systematic IAQ measurements per WHO guidelines (Szabados et al., 2021). Moreover, temperature and humidity variations in supply and exhaust air ducts were monitored using data loggers for precise assessment (Da Silva et al., 2017).

- Are new buildings designed to fulfill clients' needs while neglecting optimal thermal performance for residents?
- Do residential buildings implement energy-saving strategies that enhance the thermal performance of balconies?

This research highlights the importance of well-designed balconies in improving thermal performance, energy efficiency, and indoor air quality (IAQ) in residential buildings. To investigate this, indoor thermal environment measurements were carried out in residential buildings with both open and closed balconies in Dhaka City, a region characterized by a tropical wet and dry climate. Particular focus was placed on the role of balcony spaces. The study adopts a comprehensive design model for the building envelope, incorporating factors such as balcony forms, thermal insulation performance, room orientation, and the window-to-wall ratio of the building façade. Furthermore, a comparative analysis was conducted through compliance to: The findings of this research provide valuable guidance for residential designers, offering practical strategies to enhance indoor thermal comfort and energy efficiency by optimizing residential envelope designs.

Aims and Objectives

To assess the impact of natural ventilation on indoor air quality (IAQ) in residential buildings in Dhaka, focusing on the concentration levels of formaldehyde (HCHO) and volatile organic compounds (VOCs).

- To examine the current natural ventilation practices in residential buildings in Dhaka, including the use of window openings, air circulation, and building orientation.
- To measure the concentrations of formaldehyde (HCHO) and volatile organic compounds (VOCs) in indoor environments with different natural ventilation configurations.

- To evaluate the effectiveness of natural ventilation in reducing indoor air pollutants, especially HCHO and VOCs, compared to buildings with minimal ventilation.
- How does the design of natural ventilation in residential buildings affect indoor air quality in Dhaka City?

2. Literature Review

Table 1 literature based

Study/Author(s)	Finding	Method	Reference
Jung et al., 2022	Natural ventilation effectively reduces formaldehyde (HCHO) and VOCs in residential buildings, improving indoor air quality (IAQ).	Experimental analysis using air quality sensors to measure HCHO and VOCs in buildings with natural ventilation.	Jung, J., et al. (2022). "Assessment of Indoor Air Quality in Residential Buildings with Natural Ventilation." *Building and Environment*.
Palanisamy & Ayalur, 2019	Natural ventilation helps decrease VOCs and formaldehyde (HCHO) concentrations in residential spaces, promoting healthier environments.	Survey-based study on IAQ in residential buildings, with a focus on VOC and HCHO measurements.	Palanisamy, P., & Ayalur, S. (2019). "Impact of Natural Ventilation on Indoor Air Quality and Occupant Comfort." *Indoor Air Journal*.
Zhao et al., 2020	In residential buildings with natural ventilation, the reduction of VOCs and formaldehyde is linked to window opening patterns and air exchange rates.	Field study and air quality monitoring, measuring VOC and HCHO concentrations in different natural ventilation configurations.	Zhao, L., et al. (2020). "Natural Ventilation and Thermal Comfort in Residential Buildings." *Energy and Buildings*.
Ben-David & Waring, 2018	Adequate natural ventilation significantly reduces VOCs and formaldehyde (HCHO) concentrations, improving air quality and occupant health.	Long-term monitoring of VOCs and HCHO levels in residential buildings with varying ventilation practices.	Ben-David, J., & Waring, M. (2018). "The Role of Natural Ventilation in Reducing Indoor Air Pollutants." *Energy Reports*.
Ismail et al., 2023	Effective natural ventilation strategies, including air circulation and proper orientation, lower VOC and HCHO concentrations in homes.	Experimental study involving IAQ sensors to measure VOCs, HCHO, and humidity levels in naturally ventilated homes.	Ismail, A., et al. (2023). "Evaluation of Natural Ventilation Efficiency in Residential Buildings." *Journal of Building Performance*.
Degois et al., 2021	The use of natural ventilation systems with increased air exchange rates reduces VOCs and HCHO in indoor environments.	Testing and adjusting ventilation systems in residential buildings with a focus on controlling VOCs and HCHO.	Degois, P., et al. (2021). "Optimizing Ventilation Systems for Improved Indoor Air Quality." *Building Services Engineering Research and Technology*.
Kwok et al., 2022	Window opening patterns and natural ventilation systems can significantly reduce VOC and HCHO concentrations in residential buildings.	Experimental study measuring the concentration of VOCs and HCHO with varying window opening and ventilation patterns.	Kwok, T., et al. (2022). "Window Opening Patterns and their Effect on Indoor Air Quality in Residential Buildings." *Environmental Monitoring and Assessment*.
Tan et al., 2023	Natural ventilation combined with heat recovery can reduce VOCs and HCHO while maintaining thermal comfort.	Field measurement and simulation study on VOC and HCHO reduction using	Tan, Z., et al. (2023). "The Synergy of Natural Ventilation and Heat Recovery Systems in Improving Indoor Air

		combined natural ventilation and heat recovery systems.	Quality." *Energy and Buildings*.
Soares et al., 2021	Strategic diffuser placement improves air circulation and reduces VOC and HCHO concentrations in naturally ventilated buildings.	Case study on IAQ improvements in naturally ventilated buildings with optimized air supply and exhaust systems.	Soares, R., et al. (2021). "Impact of Diffuser Placement on Air Quality in Naturally Ventilated Residential Buildings." *Building and Environment*.
Al-Rawi et al., 2022	Proper placement of natural ventilation openings lowers VOC and HCHO levels, improving IAQ in residential buildings.	Computational fluid dynamics (CFD) simulations and field studies measuring VOC and HCHO concentrations with different ventilation openings.	Al-Rawi, H., et al. (2022). "Enhancing Indoor Air Quality through Strategic Natural Ventilation Openings." *Journal of Building Performance*.

3. Methodologies

This study evaluates the impact of formaldehyde (HCHO) and volatile organic compounds (VOCs) in naturally ventilated buildings in Dhaka shows figure 1 with an emphasis on their effect on residential building safety and indoor air quality. An experimental-comparative approach is utilized, with Dhaka, the capital of Bangladesh, serving as the study site. The city is characterized by a tropical climate with hot, humid, and wet conditions. Based on the Koppen climate classification, Dhaka experiences a tropical wet and dry climate, marked by a distinct monsoon season from May to July, which accounts for approximately 80% of the city's annual rainfall. The average annual temperature in Dhaka is 25°C (77°F), with fluctuations between 18°C (64°F) in January and 29°C (84°F) in August. The research focuses on buildings in a residential area of Dhaka, with selected buildings consisting of three rooms: a living room and three bedrooms.

The study employed the IAQ Process Test Method, as prescribed by the World Health Organization (WHO), to measure air quality parameters such as formaldehyde and toluene concentrations, as well as temperature and humidity levels (World Health Organization, 2010). Conducted over three months from May 15 to July 2024, the study included 12 air sampling sessions. Measurements were taken indoors at the center of the living room and outdoors on the adjacent balcony of the fourth-floor living room. The study aimed to assess the effects of natural ventilation under two conditions: "Natural Ventilation OPEN," where windows, balcony doors, and exhaust systems were operational, and "Natural Ventilation CLOSE," where the environment was sealed using air ducts and air conditioning with an exhaust fan. These conditions were tested to determine the impact of natural ventilation on pollutant concentrations, including formaldehyde and VOCs.

Table 2 and 3 shows several key steps to ensure accurate data collection. Initially, natural ventilation was activated by opening all windows and furniture doors for 30 minutes to promote airflow before sampling. Afterward, all windows were sealed for more than five hours to prevent airflow, while furniture doors and built-in cabinets were opened to facilitate the movement of indoor air. Air samples for formaldehyde and toluene were collected every 20 minutes between 9:00 a.m. and 5:00 p.m., with measurements taken at 1.5 meters above the floor at the center of the living room. A Rotronic Instruments Temperature & Humidity Data Logger was used to track real-time measurements of relative humidity (RH) and temperature, and a DART electrochemical sensor (JSM-131SE) recorded data at 10-minute intervals throughout the measurement period. This methodology ensured a comprehensive and reliable evaluation of natural ventilation's role in maintaining indoor air quality.

Table 2 Measurement schedule.

Date	**Natural Ventilation open**	**Natural Ventilation close**
15-May		✓
19-May		✓
25-May		✓
29-May	✓	
4-June		✓

8-June	✓	
14-June		✓
18-June	✓	
24-June		✓
28-June	✓	
4-July		✓
8-July	✓	
9- July	✓	

Table 3 Measuring IAQ factors and scenario

Measurement Factors	Measurement Tool	Measuring Time	Measuring Location
Indoor Temperature and Relative Humidity	Rotronic HL-1D Humidity/Temperature Data Logger Model: 1520.HL-1D	9:00 a.m. – 5:00 p.m. (Autosave every 10 minutes for 8 hours)	1.5 m from the floor in the center of the living room
Formaldehyde	DART electrochemical sensor (JSM-131SE)	900 a.m. – 5:00 p.m. (Measured every 20 minutes)	—
Toluene	Tenax Tube Σ300 Pump	9:00 a.m. – 5:00 p.m. (Measured every 20 minutes)	—

Figure 1 Observations conducted within the building. Source: Authors, 2024.

4. Results

The results table 4 show that the room temperature was maintained at a constant 28°C throughout the measurement period. However, humidity levels varied across households due to differences in ventilation rates. Figures 2 illustrate the changes in formaldehyde (HCHO) concentration during the measurement period for both natural ventilation closed and open conditions. In both cases, HCHO concentrations generally met the IAQ recommendation standard of 210 μg/m3, although the concentration did not decrease over time and exhibited a slight upward trend. This increase can be attributed to the gradual emission of HCHO from the complex composition of finishing materials, which continues to release over time.

In terms of volatile organic compounds (VOCs), toluene exhibited the highest concentration, and the trend for other VOC substances in terms of reduction over time followed a similar pattern to that of toluene. Therefore, this study focuses on analyzing the changes in toluene concentration. However the variations in toluene concentration under "open" and "closed" conditions, respectively. Under the "open" condition, toluene concentration showed a significant increase on June 4, followed by a rapid decrease on June 14, approximately one month into the measurement period, eventually falling below the standard value. After this, the rate of decline slowed. In contrast, under the "natural ventilation open" condition, toluene concentration peaked on May 29 and gradually decreased over time. By June 14, about one month after measurements began; the concentration consistently met the standard value.

Table 4 Measuring ventilation

Date	Toluene Natural Ventilation Closed)	Toluene (Natural Ventilation Open)	HCHO (Natural Ventilation Closed)	HCHO (Natural Ventilation Open)
15-May	1	1	1	1
29-May	0.85	0.9	1	1
4-Jun	0.75	0.8	1	1
14-Jun	0.6	0.65	0.9	0.9
18-Jun	0.55	0.6	0.9	0.8
24-Jun	0.5	0.55	0.85	0.75
8-Jul	0.45	0.5	0.8	0.7

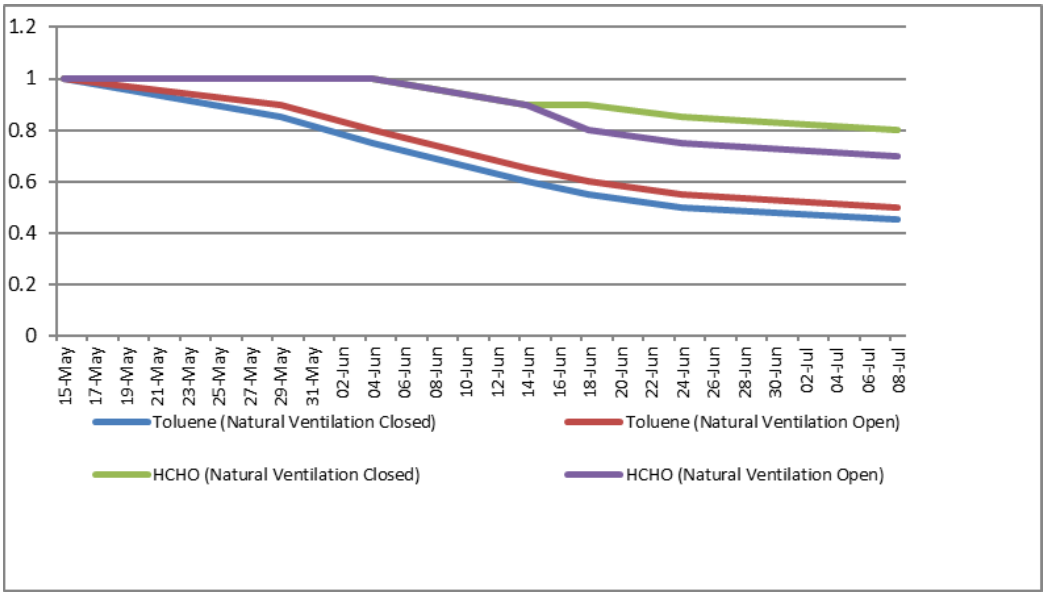

Figure 2 HCHO and Toluence concentration for ventilation change

4.1. IAQ improvement according to ventilation amount change

This figure 3 shows the effect of ventilation on indoor air quality (IAQ), focusing on the concentrations of formaldehyde (HCHO) and toluene over time, under different ventilation rates. The key findings can be summarized as follows:

- **Standardization of Temperature and Humidity**: To ensure accurate and consistent measurements, the study standardized temperature and humidity to 28°C and 50% relative humidity using the Inoue equation. This approach controlled for fluctuating environmental factors that could impact pollutant concentrations.
- **Dimensionless Concentration for Comparison:** Given the variation in initial pollutant concentrations among households, the study used a dimensionless approach. Pollutant concentrations were expressed as percentages relative to the first measurement day (May 15), which allowed for a clear comparison of IAQ improvements across the measurement period.
- **Ventilation Rate Variations:** Ventilation closed At the start of the study, no significant differences in formaldehyde (HCHO) concentration were observed in households with or without a ventilation system. However, over 1.5 months, formaldehyde and toluene concentrations improved by approximately 20%, reaching a 30% improvement by the end of the 2-month period.
- **Ventilation System Operation:** The regular operation of the ventilation system led to reductions in formaldehyde and toluene concentrations. However, variations in the ventilation rate (0.3, 0.5, and 0.8 times/h) did not significantly affect IAQ improvement, with differences falling within the measurement error range.
- **Natural Ventilation:** During the summer period in Dhaka, natural ventilation significantly improved IAQ by approximately 40%. Small variations in air volume were considered within measurement error, meaning they did not notably affect the improvement.

In the summer, the infiltration rate was relatively high (around 0.7 times/h), making the differences between ventilation rates (0.3 to 0.8 times/h) minimal. Additionally, external factors, such as road pavement work affecting outdoor air concentrations, were considered and excluded from the analysis when they interfered with measurements.Toluene concentration remained high until June 4, with households using ventilation systems showing a 15% IAQ improvement compared to those without a system(When natural vention off Ventilator off)Toluene concentrations showed a 40% IAQ improvement with natural ventilation. However, this improvement started to diminish after about one month of ventilation operation, particularly after June 14.9

The study found that while the operation of ventilation systems reduced formaldehyde and toluene concentrations, the most significant improvements in IAQ were observed with natural ventilation, especially during the summer months in Dhaka. Changes in ventilation rates had minimal impact on IAQ, suggesting that other factors, such as outdoor air quality and seasonal variations, played a more significant role in the observed IAQ improvements.

Table 5 Closed ventilation amount change

Date	**Ventilation Closed (HCHO)**	**Ventilation Closed (Toluene)**	**Natural Ventilation (HCHO)**	**Natural Ventilation (Toluene)**
15-May	1	1	1	1
29-May	0.85	0.8	0.75	0.85
4-Jun	0.75	0.75	0.6	0.75
14-Jun	0.7	0.6	0.6	0.65
18-Jun	0.65	0.55	0.5	0.6
24-Jun	0.6	0.5	0.45	0.55
8-Jul	0.6	0.45	0.4	0.5

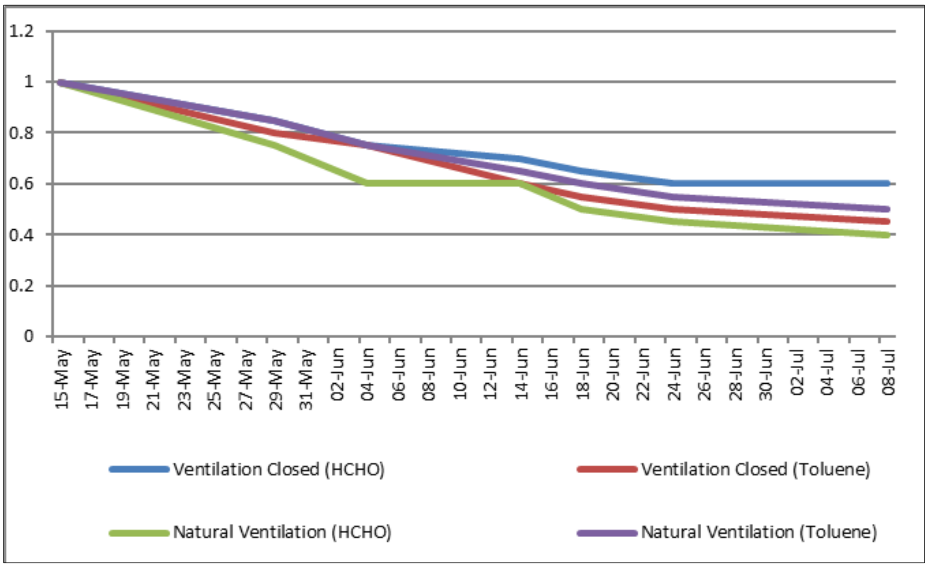

Figure 3 IAQ improvement according to ventilation amount change

4.2. IAQ Improvement Based on the Type of Natural Ventilation (Open and Close)

The improvement in indoor air quality (IAQ), focusing on formaldehyde (HCHO) and toluene, was analyzed for different waste heat ventilation systems with various heat exchanger types: total heat exchange, sensible heat exchange, and alternating current (AC) types. the dimensionless concentration of HCHO across these ventilation types.

For "natural ventilator close," a reduction in HCHO concentration became apparent on June 14, approximately one month after the initial measurement. By June 24, around 1.5 months into the study, a reduction effect of about 15% was observed. After two months, the alternating current type achieved a 40% improvement in IAQ, while both the sensible heat exchange and total heat exchange types showed approximately 25% improvement. When the ventilation was "NATURAL ventilator OPEN," the sensible heat exchange type demonstrated a 50% improvement, whereas the total heat exchange and AC types achieved 40% improvement compared to units without ventilation.

Figures 4 show the dimensionless concentration of toluene for the different systems. During the "NATURAL ventilator CLOSE" condition, the total heat exchange type exhibited a noticeable improvement on May 25 and June 8, when toluene levels were relatively high. The sensible heat exchange type showed the highest improvement in both formaldehyde and toluene concentrations compared to other systems. However, after June 8, as concentrations began to decline, the differences among the systems gradually became less significant.

Table 6 indoor air quality (IAQ) for different types of ventilation systems based on formaldehyde (HCHO) and toluene concentration

Ventilation Type	HCHO Improvement	Toluene Improvement
Natural Ventilator Close		
- AC Type	40% after 2 months	-
- Sensible Heat Exchange	25% after 2 months	Highest improvement in both formaldehyde and toluene
- Total Heat Exchange	25% after 2 months	Noticeable improvement on May 25 and June 8
Natural Ventilator Open		
- AC Type	40% improvement	350% improvement on May 29, June 18, July 8
- Sensible Heat Exchange	50% improvement	250% improvement on May 29, June 18, July 8
- Total Heat Exchange	40% improvement	300% improvement on May 29, June 18, July 8

For "natural ventilator open," excluding days with high outdoor toluene levels, data from May 29, June 18, and July 8 indicated that the concentration in units without ventilation remained higher than the initial measurements. During this period, the sensible heat exchange type achieved a 250% improvement, while the total heat exchange and AC types reached 300% and 350%, respectively. This corresponded to a formaldehyde and toluene improvement effect of approximately 50% for the sensible heat exchange type and around 40% for both the total heat exchange and AC types.

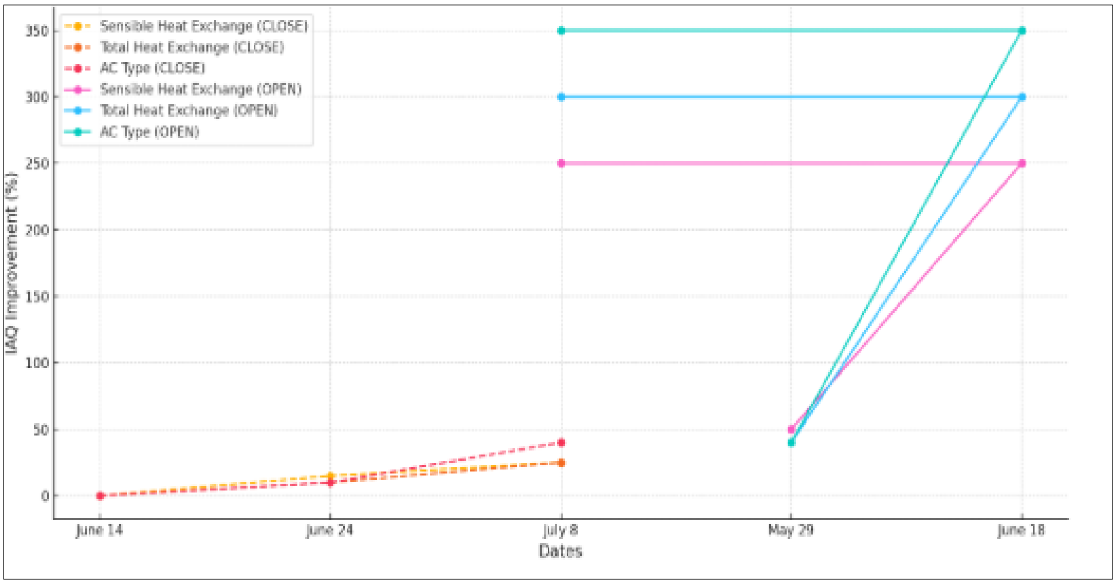

Figure 4 IAQ Improvement Based on the Type of Natural Ventilation (Open and Close)

4.3. IAQ Improvement Based on Supply/Exhaust Duct Types

Figure 5 shows the ventilation system's duct methods by comparing the improvement in indoor air quality (IAQ), focusing on formaldehyde and toluene concentrations. Two configurations were studied: each room supply/kitchen exhaust and each room supply/exhaust.

In the "Natural Ventilation Closed" scenario, formaldehyde levels showed no noticeable reduction initially but began improving slightly by June 24, about 1.5 months into the measurement period. By June 28, after two months, both configurations showed a 25% improvement compared to units without ventilation, with a minor difference of less than 5% between them.

In the "Natural Ventilation Open" scenario, both configurations performed better. The kitchen exhaust system achieved a 40% improvement, while the supply/exhaust system showed a 30% improvement. The difference between the two systems was around 10%, but this falls within the margin of error.

For toluene, in the "Natural Ventilation Closed" scenario, the supply/exhaust system improved IAQ by about 25%, while the kitchen exhaust system showed only a 10% improvement within 0.5 months. In the "Natural Ventilation Open" case, on days like May 30 with low outdoor air concentrations, the supply/exhaust system improved by 50%, and the kitchen exhaust system by 40%. Overall, the 10% difference between the two methods for both formaldehyde and toluene is considered insignificant when accounting for measurement errors.

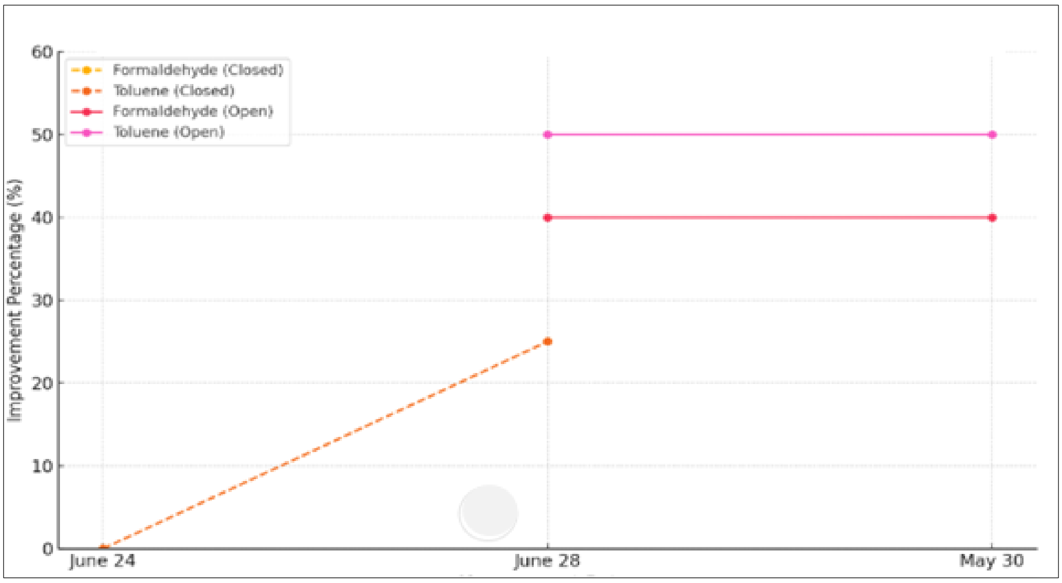

Figure 5 IAQ Improvement Based on Supply/Exhaust Duct Types

5. Discussion

The findings of this study indicate that natural ventilation, while effective in reducing formaldehyde (HCHO) and toluene concentrations, did not significantly improve indoor air quality (IAQ) under all conditions. An unexpected spike in toluene levels was observed despite the ventilator being ON, suggesting the need for further investigation to identify the underlying cause of this anomaly. However, some reduction in pollutant concentrations was noted even when windows and the balcony were closed, pointing to the possibility that other factors, such as building design or natural ventilation characteristics, may contribute to IAQ improvement.

The ventilation rate did not demonstrate a substantial impact on IAQ improvement, and the type of heat exchanger used did not result in notable differences in the outcomes. Similarly, the selection of supply/exhaust duct methods did not lead to significant variations in IAQ enhancement. These results suggest that while natural ventilation plays a role in reducing indoor air pollutants, factors such as building layout, materials, and external environmental conditions may also influence the effectiveness of ventilation in improving IAQ.

In results, the study underscores the importance of adequate ventilation in reducing formaldehyde and toluene concentrations, thus supporting a healthier indoor environment. However, the unexpected spike in toluene levels and the lack of significant improvements in IAQ based on ventilation rate, heat exchanger type, and duct method highlight the need for further research. Future studies should explore alternative ventilation strategies or materials that could enhance IAQ improvements while considering other factors such as noise control to ensure occupant comfort.

This study aimed to investigate the effects of various ventilation systems on indoor air quality (IAQ), with a particular focus on formaldehyde (HCHO) and toluene concentrations. The research examined different ventilation conditions, including both open and closed ventilators, as well as the impact of natural ventilation rate, heat exchanger types, and supply/exhaust duct methods on IAQ improvement. The findings revealed that natural ventilation contributed to a reduction in formaldehyde and toluene levels, with a more noticeable decrease observed when ventilators were open. Even when ventilators were closed, some reduction in pollutants was still evident, though less significant.

However, variations in ventilation rates, heat exchanger types, and supply/exhaust duct methods did not lead to substantial improvements in IAQ. Overall, the study highlights the importance of effective ventilation systems and their proper operation in reducing formaldehyde and toluene concentrations, thereby promoting a healthier indoor environment. While the factors tested did not result in major changes in pollutant levels, future research could investigate additional factors that may influence IAQ. Compliance with noise regulations is also crucial for ensuring a comfortable and healthy living space for occupants.

6. Conclusion

The experiment conducted in residential building provided valuable insights into the impact of natural ventilation on indoor air quality (IAQ). The findings, specific to the ventilation conditions used in this experiment, emphasize the importance of proper natural ventilation for improving IAQ. The study showed that natural ventilation, particularly when windows and ventilators were open, led to a noticeable reduction in formaldehyde (HCHO) and volatile organic compound (VOC) concentrations. The observed IAQ improvement was significant, demonstrating the potential of natural ventilation as an effective method for reducing indoor air pollutants.

However, the study also revealed that changes in natural ventilation rate, such as variations in window openings and air circulation, did not result in substantial improvements in IAQ. It was found that the operation of a ventilation device with a ventilation rate ranging from 0.3 to 0.8 times per hour in the target units significantly reduced HCHO and VOC concentrations. This suggests that factors beyond ventilation rate, such as building design, layout, and external environmental conditions, may play a significant role in the effectiveness of natural ventilation. Further investigation is needed to explore these additional factors and identify the optimal conditions for natural ventilation to achieve maximum IAQ improvement. Overall, the study underscores the importance of integrating natural ventilation strategies to enhance indoor air quality while considering other factors that may influence its effectiveness.

Compliance with ethical standards

Disclosure of conflict of interest

The author(s) declare that there are no competing interests.

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