International Journal of Science and Research Archive

eISSN: 2582-8185

Cross Ref DOI: 10.30574/ijsra

Journal homepage: https://ijsra.net/

(Research Article)

Check for updates

SHORT-TERM MONITORING OF INDOOR FORMALDEHYDE (HCHO) AND TOTAL VOLATILE ORGANIC COMPOUND (TVOC) CONCENTRATIONS ACROSS RESIDENTIAL MICROENVIRONMENTS USING A PORTABLE LOW-COST AIR QUALITY SENSOR IN BALLARI, KARNATAKA, INDIA

Shalini V [1,*] and Shilpa Kulkarni [2]

[1] Department of Physics, T.S.H.M.S Government First Grade College, Siruguppa-583121, Karnataka, India.
[2] Department of Physics, SKNG Government First Grade College, Gangavati-583227, Karnataka, India.
* Corresponding Author

International Journal of Science and Research Archive, 2026, 20(02), 379–388

Publication history: Received on 04 July 2026; revised on 13 August 2026; accepted on 15 August 2026

Article DOI: https://doi.org/10.30574/ijsra.2026.20.2.1636

ABSTRACT

Indoor air quality is an important concern as people spend much of their time inside buildings and may be exposed to pollutants from various indoor activities. This study examined the hourly concentrations of formaldehyde (HCHO) and total volatile organic compounds (TVOC) in a residential building in Ballari, Karnataka, India. Monitoring was carried out in the living room, kitchen, and bedroom for 15 days during March and April 2025 using a portable low-cost air quality monitor. HCHO, TVOC, temperature, and relative humidity were recorded hourly between 06:00 and 23:00 h. The results showed noticeable differences in pollutant levels between the three indoor environments. The kitchen recorded the highest HCHO (0.199 mg/m^3) and TVOC (0.826 mg/m^3) concentrations, mainly during cooking and gas stove use. The living room showed moderate levels, with higher concentrations during evening hours, whereas the bedroom generally had lower and more stable concentrations. HCHO and TVOC showed similar variations, suggesting the influence of common indoor sources. Cooking, ventilation, and occupant activities were found to be important factors affecting indoor pollutant levels. The study demonstrates the usefulness of low-cost monitors for residential IAQ assessment and emphasizes the need for proper kitchen ventilation and adequate air exchange to reduce indoor pollutant exposure.

Keywords: Indoor Air Quality, Formaldehyde (HCHO), Total Volatile Organic Compounds (TVOC), Low-Cost Sensors, Residential Building, Kitchen Emissions, Ventilation, Public Health.

1 INTRODUCTION

Indoor air quality (IAQ) has become a major environmental and public health concern because people spend approximately 80–90% of their time indoors, where exposure to air pollutants can adversely affect health [1, 2]. Poor indoor air quality is associated with respiratory diseases, eye and throat irritation, allergies, headaches, and other chronic health problems [3, 4]. Among indoor pollutants, formaldehyde (HCHO) and total volatile organic compounds (TVOCs) are of particular concern due to their widespread presence in residential buildings and their potential health risks [5, 6].

Formaldehyde is emitted from building materials, furniture, paints, adhesives, and household products [6, 7], while TVOCs originate from cooking, cleaning agents, paints, air fresheners, and other consumer products [8, 9]. Indoor concentrations of these pollutants are influenced by occupant activities, ventilation, temperature, and humidity [10, 11]. Cooking is considered one of the major sources of indoor HCHO and TVOC emissions, especially in residential kitchens [8, 11].

Recent advances in low-cost air quality sensors have enabled continuous and real-time monitoring of indoor pollutants at a relatively low cost. These sensors provide an effective alternative for assessing indoor air quality and identifying pollution trends in residential environments [12, 13, 14].

In India, studies on indoor HCHO and TVOC concentrations in residential buildings are still limited [15, 16], particularly in smaller cities such as Ballari, Karnataka. Therefore, the present study was conducted to monitor hourly variations of HCHO and TVOC concentrations in the living room, kitchen, and bedroom of a residential building using a portable low-cost sensor. The study aims to evaluate the influence of indoor activities and ventilation on pollutant levels and to provide baseline information for improving residential indoor air quality.

Objectives

- To monitor indoor HCHO concentrations in different residential rooms.
- To determine TVOC concentrations across residential microenvironments.
- To compare indoor air quality among the living room, kitchen, and bedroom.
- To study the influence of temperature and humidity on concentration of pollutants.
- To evaluate the usefulness of a portable low-cost sensor for residential IAQ monitoring.

2 MATERIALS AND METHODS

2.1 Study Area

Figure 1: Location of the study site

The study was carried out in a residential building in Ballari, Karnataka, India (15.161924°N, 76.942187°E), located in a relatively quiet neighbourhood about 500 m from NH-167. A municipal park adjacent to the building provides a regular setting for walking and recreational activities, particularly during the morning and evening, while nearby traffic and occasional waste burning may influence outdoor air quality. Indoor HCHO and TVOC measurements were conducted under normal household conditions in three commonly occupied spaces: the living room (4.572 × 2.438 m), kitchen (2.438 × 3.658 m), and bedroom (3.048 × 3.658 m). The residence is occupied by three people and is naturally ventilated through windows and the main door. Potential indoor PM sources included cooking, incense burning during religious activities, use of electrical appliances, air conditioning, and infiltration of outdoor air through openings. The floor plan and locations of the monitored rooms are presented in Figure 1 and 2.

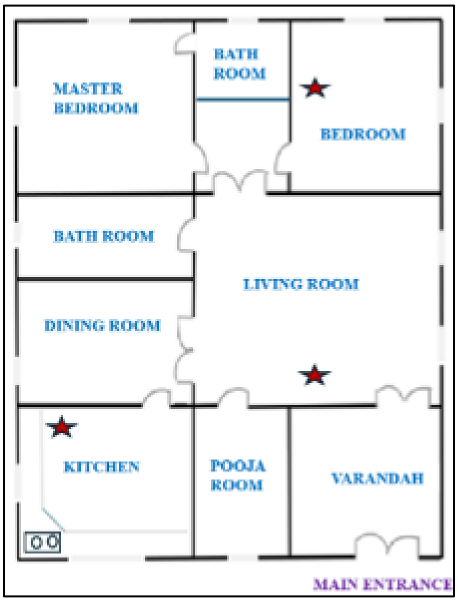

Figure 2: Floor plan of the residence with sensor placement locations

2.2 Monitoring Period

The study was conducted during March–April 2025, with hourly measurements recorded from 06:00 h to 23:00 h. Monitoring was carried out for 15 consecutive days, with the instrument placed in the living room from 21–26 March 2025, then in the kitchen from 27–31 March 2025, and finally in the bedroom from 1–5 April 2025, with five monitoring days assigned to each environment.

2.3 Instrumentation

A portable low-cost indoor air quality monitor, SMILEDRIVE (Version 1.0), was used to measure formaldehyde (HCHO) (mg/m^3), Total Volatile Organic Compounds (TVOC) (mg/m^3), Temperature (°C) and Relative Humidity (%).

2.4 Data Collection

The monitor was placed at approximately 1.2 m (4 ft) above the floor in each room. Hourly measurements of HCHO, TVOC, temperature, and humidity were recorded. Indoor activities such as cooking, ventilation, and air-conditioner operation were also noted.

2.5 Data Analysis

The data were analysed using Microsoft Excel. Descriptive statistics and line graphs were used to evaluate hourly variations in HCHO and TVOC concentrations across the three rooms.

3 RESULTS AND DISCUSSION

3.1 Hourly Variation of Indoor HCHO

3.1.1 In Living Room

Figure 3 presents the hourly variation of indoor formaldehyde (HCHO) concentrations measured in the living room over five consecutive monitoring days (21–26 March 2025). Overall, HCHO concentrations varied from 0.064 to 0.134 mg/m^3, indicating noticeable temporal fluctuations associated with occupant activities, ventilation conditions, and meteorological influences.

During the early morning hours (06:00–09:00), HCHO concentrations remained relatively stable, ranging between 0.078 and 0.091 mg/m^3. These concentrations likely represent the background emission from indoor materials such as wooden furniture, particleboard, adhesives, synthetic fabrics, and painted surfaces. Formaldehyde is continuously emitted from these materials through off-gassing, resulting in relatively constant baseline concentrations even in the absence of significant indoor activities [17].

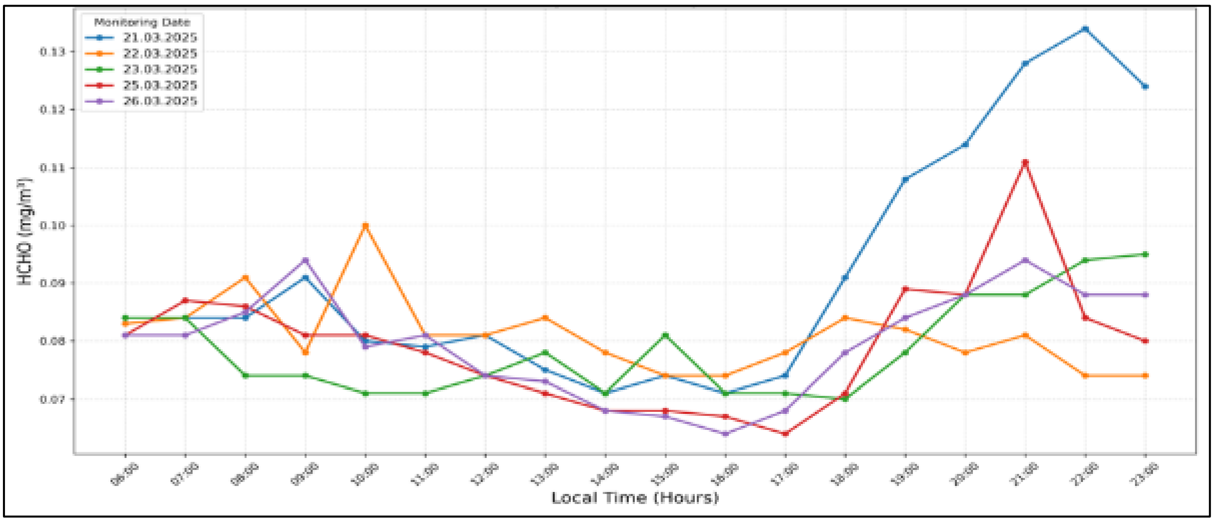

Figure 3: Hourly variation of indoor HCHO during 5 consecutive days in living room

A gradual decline in HCHO concentration was observed during the afternoon (13:00–17:00), when values decreased to approximately 0.064–0.074 mg/m^3. This reduction coincided with increased ambient temperature and improved natural ventilation through open doors and windows. Enhanced air exchange promotes dilution and removal of indoor pollutants, thereby reducing formaldehyde accumulation.

The most significant increase occurred during the evening period (18:00–22:00). On 21 March, the HCHO concentration increased continuously from 0.091 mg/m^3 at 18:00 h to a maximum of 0.134 mg/m^3 at 22:00 h, representing nearly a twofold increase relative to the afternoon minimum. Field observations indicated rainfall and high humidity during this period, which reduced natural ventilation and led to pollutant accumulation in the living room. Increased occupancy during evening hours may also have contributed through human activities and reduced ventilation.

Although similar evening increases were observed on the remaining monitoring days, their magnitudes were comparatively lower, suggesting that meteorological conditions strongly influenced pollutant accumulation.

Overall, the living room exhibited a clear diurnal variation characterised by lower daytime concentrations and elevated evening concentrations. These findings agree with previous indoor air quality studies that identify inadequate ventilation and increased occupancy as major determinants of indoor formaldehyde accumulation.

3.1.2 In Kitchen

Figure 4 shows the hourly variation of formaldehyde concentrations measured in the kitchen between 27 and 31 March 2025. Among the three monitored indoor environments, the kitchen demonstrated the greatest variability in HCHO concentrations due to cooking-related activities.

HCHO concentrations ranged from 0.061 to 0.199 mg/m^3, substantially exceeding the concentrations measured in both the living room and bedroom during cooking periods.

The highest concentration (0.199 mg/m^3) occurred on 28 March at 10:00 h, immediately following intensive cooking activities. Another elevated concentration (0.192 mg/m^3) was observed at 09:00 h on the same day, confirming that cooking was the primary contributor to indoor formaldehyde emissions.

Additional peaks were observed during breakfast preparation (08:00–10:00 h) and evening meal preparation (20:00–22:00 h), particularly on 29 March and 31 March, when comments indicated that the cooking stove had recently been used. These observations demonstrate that the combustion of cooking gas, the heating of edible oils, and the thermal degradation of food ingredients significantly increase formaldehyde concentrations [18].

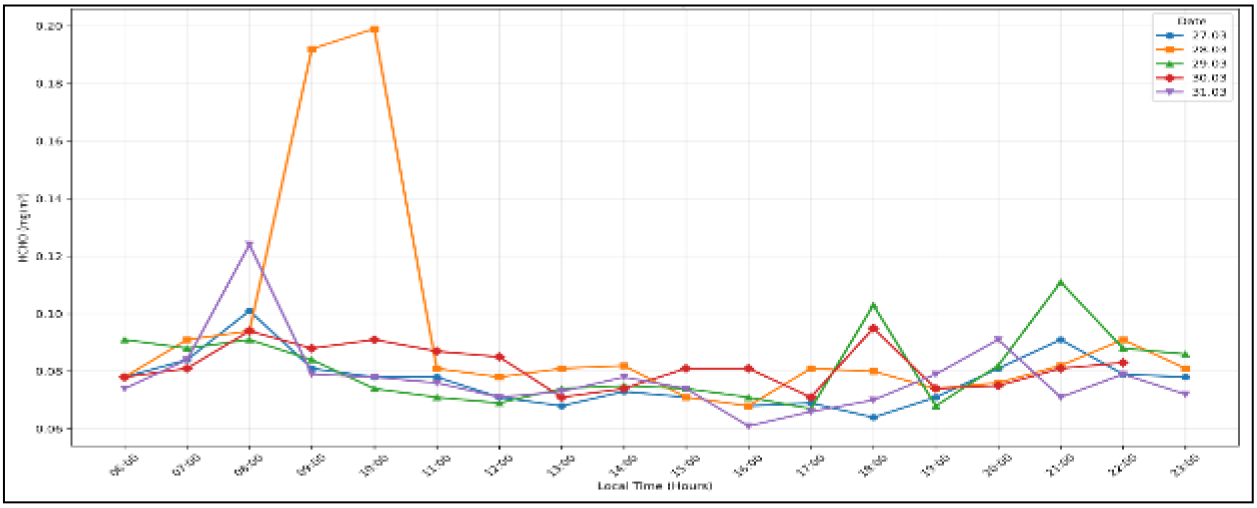

Figure 4: Hourly variation of indoor HCHO during 5 consecutive days in kitchen

Conversely, during periods without cooking, HCHO concentrations decreased substantially to levels below 0.080 mg/m^3, indicating rapid pollutant dilution after cooking activities.

These results indicate that cooking is one of the dominant indoor sources of formaldehyde in residential buildings.

3.1.3 In Bedroom

Figure 5 shows the hourly variation in HCHO concentration recorded in the bedroom from 1 to 5 April 2025. In comparison with the kitchen and living room, the bedroom showed relatively small fluctuations in HCHO levels, with concentrations ranging from 0.068 to 0.105 mg/m^3. Most of the recorded values were within the range of 0.075–0.090 mg/m^3, suggesting that the bedroom had fewer significant indoor sources of formaldehyde. The absence of activities such as cooking and combustion may have contributed to the relatively stable concentrations observed in this room.

A noticeable decrease in HCHO concentration was observed during periods when the air conditioner was operating and the windows were open. This may be attributed to increased air movement and air exchange, which can help remove accumulated pollutants from the indoor environment. The highest concentration of 0.105 mg/m^3 was observed on 2 April at 21:00 h, when the air conditioner was switched off and ventilation was comparatively limited. A similar elevated value of 0.104 mg/m^3 was recorded on 5 April, which coincided with cloudy weather and reduced air movement. Overall, the observed variations indicate that ventilation conditions and air exchange significantly influence HCHO levels in residential bedrooms.

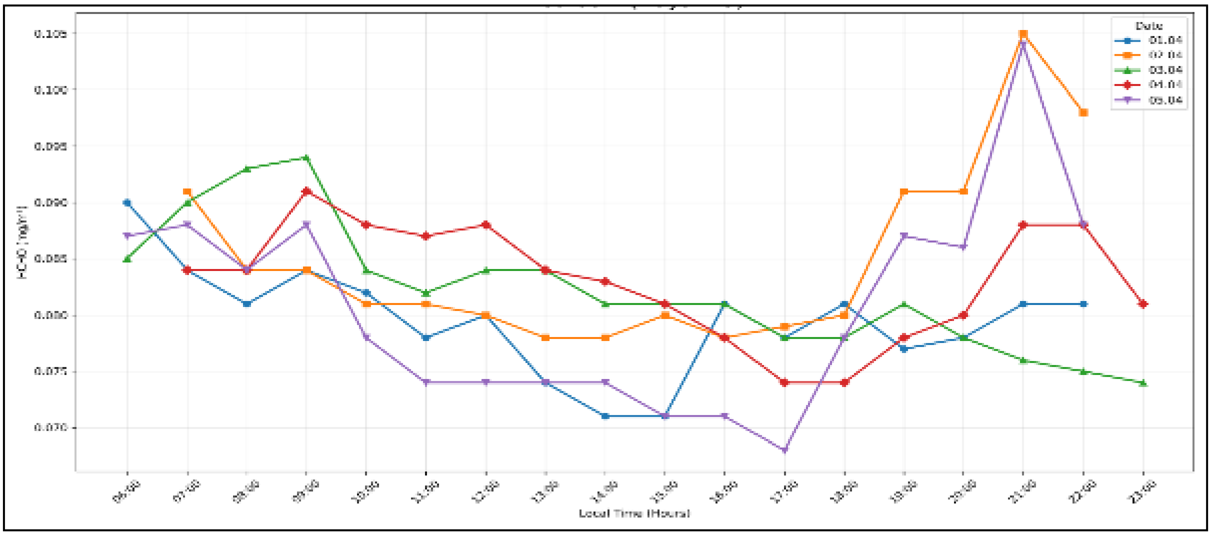

Figure 5: Hourly variation of indoor HCHO during 5 consecutive days in bedroom

3.2 Hourly Variation of Indoor TVOC

3.2.1 In Living Room

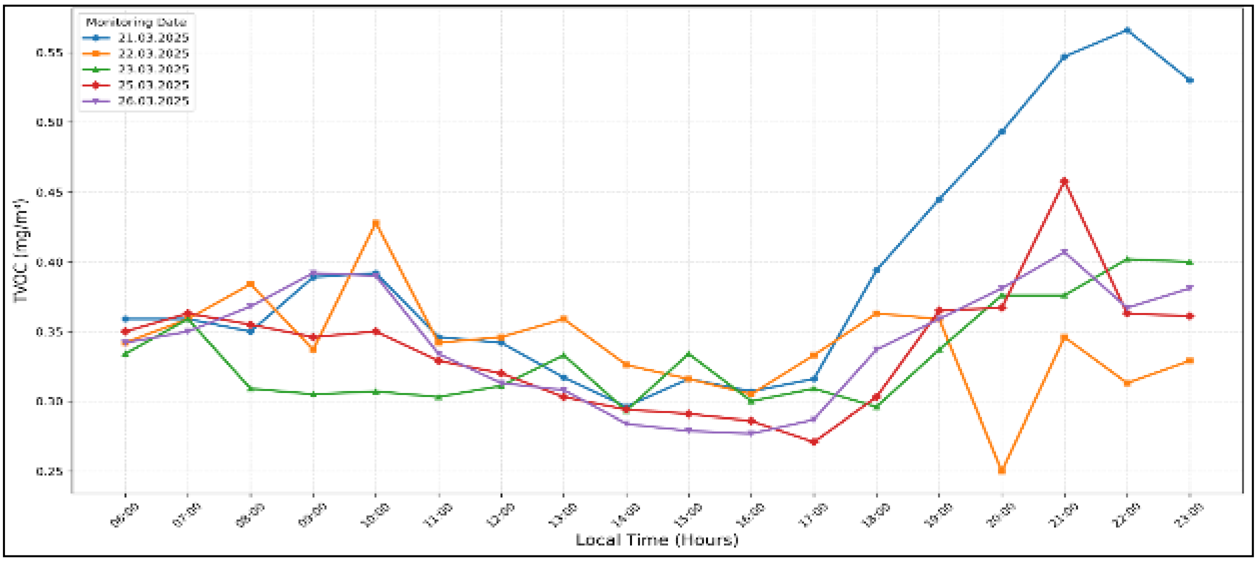

Figure 6: Hourly variation of indoor TVOC during 5 consecutive days in living room

Figure 6 illustrates the hourly variation of Total Volatile Organic Compound (TVOC) concentrations measured simultaneously with HCHO in the living room. TVOC concentrations ranged from 0.250 to 0.566 mg/m^3, exhibiting temporal variations similar to those observed for HCHO.

Morning concentrations remained relatively constant between 0.330 and 0.390 mg/m^3, indicating continuous emissions from household materials and consumer products. During the afternoon period, TVOC concentrations gradually decreased to values near 0.270–0.320 mg/m^3, corresponding to periods of increased ventilation and reduced indoor occupancy.

The highest TVOC concentration (0.566 mg/m^3) was recorded at 22:00 h on 21 March, which coincided with the highest HCHO concentration measured during the study period. This simultaneous increase strongly suggests that both pollutants originated from common indoor emission sources. The increase may be attributed to emissions from furniture, household cleaning products, air fresheners, cooking residues [19], and limited air exchange following rainfall.

Unlike HCHO, TVOC represents a mixture of numerous volatile organic compounds emitted from multiple indoor sources. Consequently, TVOC exhibited slightly greater variability than HCHO throughout the monitoring period. Nevertheless, both pollutants followed nearly identical temporal trends, indicating that indoor environmental conditions affected their concentrations similarly.

The evening increase emphasizes the importance of maintaining adequate ventilation during periods of high indoor occupancy to minimize exposure to volatile organic compounds.

3.2.2 In Kitchen

Figure 7 illustrates the temporal variation of TVOC concentrations in the kitchen. Concentrations ranged from 0.261 to 0.826 mg/m^3, representing the highest TVOC levels observed in the entire study.

Extremely high TVOC concentrations were recorded during cooking activities on 28 March, reaching 0.825 mg/m^3 and 0.826 mg/m^3 at 09:00 and 10:00 h, respectively. Similar but less pronounced increases occurred on 29 March during dinner preparation and on 31 March immediately after stove operation.

Cooking can be an important source of volatile organic compounds (VOCs) indoors. These compounds may be released from activities such as fuel combustion, heating of cooking oils and spices, and the breakdown of food materials at high temperatures. As a result, VOC levels in kitchens are often higher than those measured in other areas of a residential building.

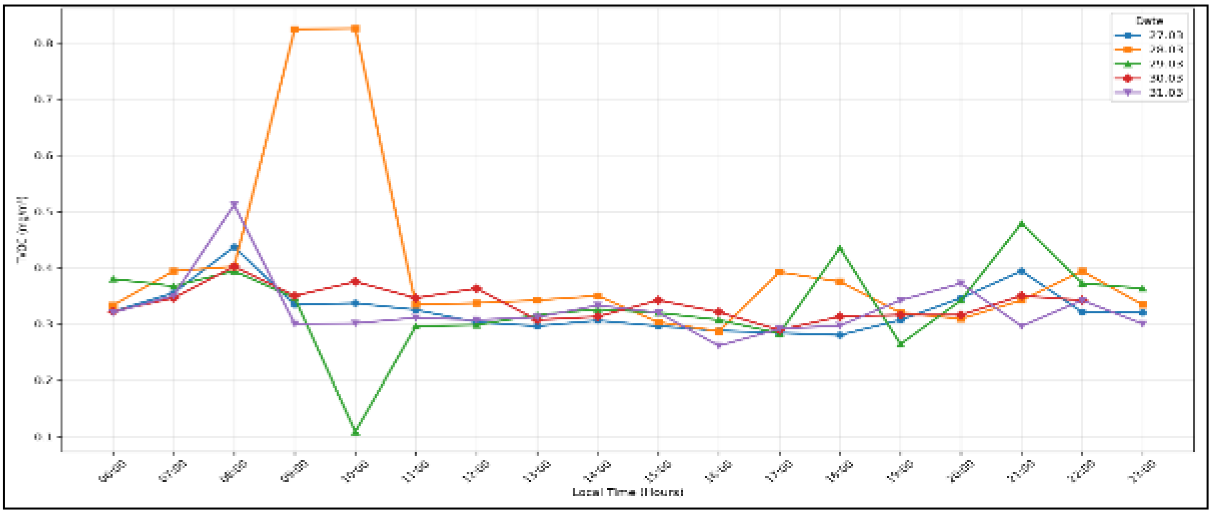

Figure 7: Hourly variation of indoor TVOC during 5 consecutive days in kitchen

During non-cooking periods, TVOC concentrations decreased rapidly and remained between 0.260 and 0.350 mg/m^3, demonstrating the effectiveness of pollutant dilution after cooking ceased.

The close association between cooking activities and the observed increases in TVOC concentrations suggests that cooking is the major contributor to VOC emissions in the residential kitchen.

3.2.3 In Bedroom

Figure 8 illustrates TVOC concentrations measured in the bedroom. Concentrations ranged from 0.284 to 0.445 mg/m^3, which were considerably lower than those observed in the kitchen but comparable to those measured in the living room.

TVOC concentrations remained relatively constant throughout most of the monitoring period, indicating minimal indoor pollutant generation. However, temporary increases occurred during periods of reduced ventilation, especially when windows remained closed or air conditioning was switched off.

The highest TVOC concentration (0.445 mg/m^3) occurred on 5 April at 21:00 h, coinciding with cloudy weather and reduced natural ventilation. Conversely, periods with open windows exhibited lower TVOC concentrations, highlighting the effectiveness of natural ventilation in improving bedroom air quality.

The relatively stable TVOC concentrations indicate that bedrooms are generally less influenced by indoor pollutant sources than kitchens, with ventilation becoming the primary controlling factor.

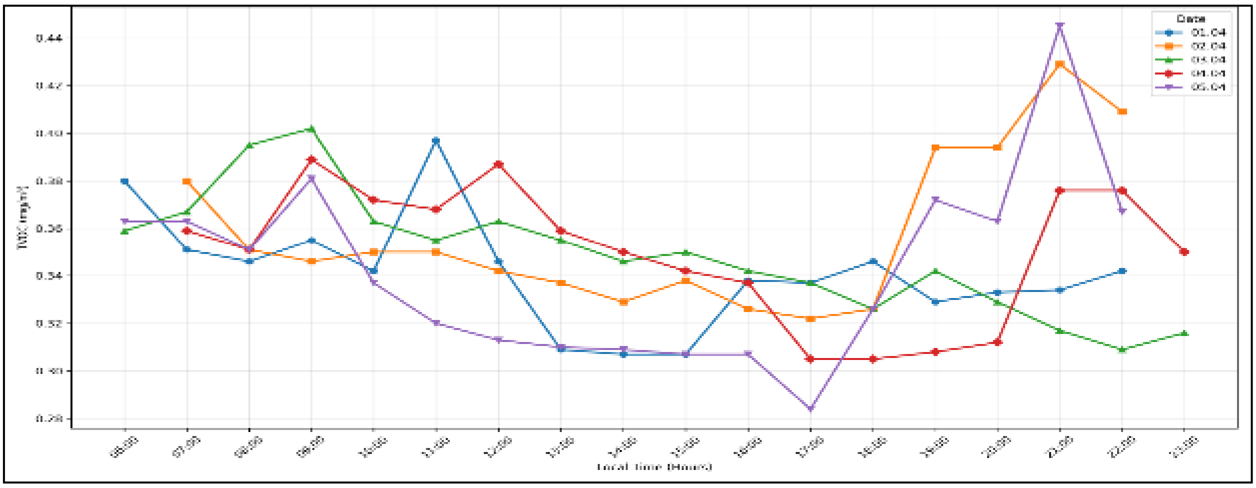

Figure 8: Hourly variation of indoor TVOC during 5 consecutive days in bedroom

3.3 Mean Concentrations of Air Quality Parameters

Table 1: Descriptive Statistics of Indoor Air Quality Parameters in Different Rooms

Parameter	**Living Room**		**Kitchen**		**Bedroom**	
	Mean	SD	Mean	SD	Mean	SD
HCHO (mg/m^3)	0.082	0.017	0.085	0.025	0.082	0.008
TVOC (mg/m^3)	0.354	0.066	0.359	0.108	0.349	0.032
Temperature (°C)	31.50	1.38	32.50	1.63	29.10	2.10
Relative Humidity (%)	45.80	8.20	32.80	9.60	49.80	10.90

Table 1 presents the descriptive statistics (mean and standard deviation) of indoor formaldehyde (HCHO), total volatile organic compounds (TVOC), temperature, and relative humidity measured in the living room, kitchen, and bedroom of the residential building during the monitoring period. The results demonstrate noticeable variations among the three rooms, reflecting the influence of indoor activities, ventilation, and room usage on indoor air quality.

The mean HCHO concentration was highest in the kitchen (0.085 ± 0.025 mg/m^3), followed by the living room (0.082 ± 0.017 mg/m^3) and the bedroom (0.082 ± 0.008 mg/m^3). Although the average HCHO concentrations in the living room and bedroom were similar, the kitchen exhibited a considerably larger standard deviation, indicating greater fluctuations in formaldehyde concentrations. These variations are primarily attributed to cooking activities, gas stove combustion, and the release of pollutants from heated cooking oils and food ingredients. In contrast, the bedroom recorded the lowest standard deviation, suggesting relatively stable HCHO concentrations due to fewer indoor emission sources and comparatively better ventilation.

Similarly, the mean TVOC concentration was highest in the kitchen (0.359 ± 0.108 mg/m^3), followed by the living room (0.354 ± 0.066 mg/m^3) and the bedroom (0.349 ± 0.032 mg/m^3). The markedly higher standard deviation observed in the kitchen indicates substantial temporal variation caused by intermittent cooking activities. Elevated TVOC concentrations during meal preparation confirm that cooking is one of the major contributors to volatile organic compound emissions in residential environments. The bedroom exhibited the lowest variability in TVOC concentrations, indicating comparatively cleaner and more stable indoor air conditions.

The average indoor temperature was highest in the kitchen (32.50 ± 1.63°C), followed by the living room (31.50 ± 1.38°C), while the bedroom recorded the lowest temperature (29.10 ± 2.10°C). The higher kitchen temperature can be attributed to continuous heat generated from cooking appliances and stove operation. Conversely, the lower bedroom temperature may be associated with air-conditioner use and reduced heat-generating activities.

Regarding relative humidity, the bedroom recorded the highest average value (49.80 ± 10.90%), followed by the living room (45.80 ± 8.20%), whereas the kitchen exhibited the lowest humidity (32.80 ± 9.60%). The comparatively higher humidity in the bedroom may be due to reduced ventilation, air-conditioner operation, and lower indoor temperatures, while the lower humidity observed in the kitchen is likely associated with higher temperatures and increased air movement during cooking.

3.4 Comparative Discussion of Indoor Air Quality Across the Three Rooms

A comparison of the three monitored rooms revealed significant differences in indoor air quality. The kitchen recorded the highest mean HCHO (0.085 ± 0.025 mg/m^3) and TVOC (0.359 ± 0.108 mg/m^3) concentrations, mainly due to cooking activities, gas stove combustion, and emissions from heated cooking oils. The higher standard deviation also indicates greater fluctuations in pollutant levels during meal preparation.

The living room exhibited moderate HCHO (0.082 ± 0.017 mg/m^3) and TVOC (0.354 ± 0.066 mg/m^3) concentrations, with pollutant levels increasing during evening hours because of higher occupancy and reduced ventilation. In contrast, the bedroom showed the lowest and most stable HCHO (0.082 ± 0.008 mg/m^3) and TVOC (0.349 ± 0.032 mg/m^3) concentrations, reflecting fewer indoor emission sources and better pollutant stability.

Temperature was highest in the kitchen (32.50 ± 1.63°C), while the bedroom recorded the highest relative humidity (49.80 ± 10.90%). Overall, the results indicate that cooking activities, room function, ventilation, and occupant behaviour are the primary factors influencing indoor HCHO and TVOC concentrations. The findings highlight the importance of adequate kitchen ventilation and regular indoor air quality monitoring to minimize pollutant exposure and improve residential indoor environments.

4 FINDINGS OF THE STUDY

- The kitchen recorded the highest HCHO and TVOC concentrations due to cooking activities and gas stove combustion.
- The living room showed moderate pollutant levels, with higher concentrations during evening hours because of reduced ventilation and increased occupancy.
- The bedroom exhibited the lowest and most stable concentrations, indicating better indoor air quality.
- Both HCHO and TVOC followed similar temporal patterns, suggesting common indoor emission sources.
- Pollutant concentrations generally decreased during the afternoon due to improved natural ventilation and increased air circulation.
- Cooking, ventilation, weather conditions, and occupant activities were identified as the major factors influencing indoor air quality.

Suggestions

- Install and regularly use kitchen exhaust fans or chimneys during cooking.
- Improve natural ventilation by opening windows and doors whenever possible.
- Use low-emission furniture, paints, and household products to reduce indoor pollutant emissions.
- Avoid excessive use of air fresheners, incense sticks, and aerosol sprays.
- Maintain air-conditioning and ventilation systems regularly.
- Conduct periodic indoor air quality monitoring using low-cost sensors.

5 CONCLUSION

The study demonstrated that indoor HCHO and TVOC concentrations vary significantly with room type, occupant activities, and ventilation conditions. The kitchen exhibited the highest pollutant concentrations, mainly due to cooking, while the bedroom maintained the lowest levels because of fewer indoor emission sources. The living room showed moderate concentrations, with higher levels during evening hours. Overall, improved ventilation, effective kitchen exhaust systems, and continuous monitoring using low-cost sensors can significantly enhance indoor air quality and reduce occupants' exposure to harmful pollutants in residential buildings.

STATEMENTS ON COMPLIANCE WITH ETHICAL STANDARDS

Acknowledgments

The author sincerely thanks the Department of PG studies in Physics, SSA Government First Grade College (Autonomous), Ballari, for providing instrument for the measurement.

Disclosure of conflict of interest

The authors declare no conflict of interest.

REFERENCES

[1] Klepeis NE, Nelson WC, Ott WR, Robinson JP, Tsang AM, Switzer P, et al. (2001). The National Human Activity Pattern Survey (NHAPS): a resource for assessing exposure to environmental pollutants. J Expo Anal Environ Epidemiol., 11(3) :231-52.

[2] Committee on Indoor Pollutants, National Research Council (US). Indoor Pollutants. Washington, DC: National Academies Press. Available from: NCBI Bookshelf, NBK234047.

[3] Malta, G., Montana, A., Argo, A., Zerbo, S., Plescia, F., & Cannizzaro, E. (2025). Medical–Legal Liability and Indoor Air Pollution in Non-Industrial Environments and Perspectives for Maternal and Child Health. *Children*, *12*(10), 1287. https://doi.org/10.3390/children12101287.

[4] National Institute of Environmental Health Sciences. Indoor Air Quality. Available from: https://www.niehs.nih.gov/health/topics/agents/indoor-air.

[5] Chatterjee A, Pál L, Lovas S, McKee M, Diószegi J, Kovács N, Szűcs S. (2026). Assessment of health risks from exposure to indoor volatile organic compounds in European educational buildings. Sci Rep., 16(1): 6554. doi: 10.1038/s41598-026-37072-2.

[6] Negrete-Carrillo, K., Salvador-Carlos, J., Valdez-Salas, B., Beltrán-Partida, E., Castillo-Saenz, J., & Gamboa-Becerra, R. (2026). Formaldehyde Emissions from Wood Materials and Their Impact on Indoor Air Quality. Sustainability, 18(14), 7176. https://doi.org/10.3390/su18147176

[7] Chang, T., Wang, J., Lu, J., Shen, Z., Huang, Y., Sun, J., Xu, H., Wang, X., Ren, D. and Cao, J. (2019). Evaluation of Indoor Air Pollution during Decorating Process and Inhalation Health Risks in Xi'an, China: A Case Study. Aerosol Air Qual. Res., 19: 854-864. https://doi.org/10.4209/aaqr.2018.07.0261

[8] Alves CA, Vicente ED, Evtyugina M, Vicente AMP, Sainnokhoi TA, Kováts N.(2021). Cooking activities in a domestic kitchen: Chemical and toxicological profiling of emissions. Sci Total Environ. https://doi.org/10.1016/j.scitotenv.2021.145412

[9] Nicole W.(2014). Cooking up indoor air pollution: emissions from natural gas stoves. Environ Health Perspect., 122(1): A27. doi: 10.1289/ehp.122-A27.

[10] Lee K, Choi JH, Lee S, Park HJ, Oh YJ, Kim GB, Lee WS, Son BS. (2018). Indoor levels of volatile organic compounds and formaldehyde from emission sources at elderly care centers in Korea. PLoS One., 13(6): e0197495. doi: 10.1371/journal.pone.0197495.

[11] Kalia S, Mishra N, Ghose P. (2024). Indoor air quality assessment of an existing apartment located in Indian tropical city, Bhubaneswar. J Air Pollut Health, 9(3):383-402.

[12] Lopes, S. I., Orłowski, C., Branco, P. T. B. S., Karatzas, K., Villena, G., Saffell, J., Marques, G., Sousa, S. I. V., Lenartz, F., Bergmans, B., Bigi, A., Pflanzner, T., & Ródenas García, M. (2025). Low-Cost Sensor Systems and IoT Technologies for Indoor Air Quality Monitoring: Instrumentation, Models, Implementation, and Perspectives for Validation. Sensors, 25(24), 7567. https://doi.org/10.3390/s25247567

[13] Yu, Y., Gola, M., Settimo, G., Buffoli, M., & Capolongo, S. (2024). Feasibility and Affordability of Low-Cost Air Sensors with Internet of Things for Indoor Air Quality Monitoring in Residential Buildings: Systematic Review on Sensor Information and Residential Applications, with Experience-Based Discussions. Atmosphere, 15(10), 1170. https://doi.org/10.3390/atmos15101170

[14] H. Chojer, P.T.B.S. Branco, F.G. Martins, S.I.V. Sousa, (2024). A novel low-cost sensors system for real-time multipollutant indoor air quality monitoring – Development and performance, Building and Environment, Volume 266,112055. https://doi.org/10.1016/j.buildenv.2024.112055

[15] Datta A, Suresh R, Gupta A, Singh D, Kulshrestha P. (2017). Indoor air quality of non-residential urban buildings in Delhi, India. Int J Sustain Built Environ., 6(2):412-20.

[16] Prasenjit Karmakar, Swadhin Pradhan, Sandip Chakraborty (2024). Exploring Indoor Air Quality Dynamics in Developing Nations: A Perspective from India. ACM Journal on Computing and Sustainable Societies, 2(3), Article No.: 40: 1 – 40, https://doi.org/10.1145/3685694.

[17] Mohamed Z.M. Salem, Martin Böhm, Jaromír Srba, Jitka Beránková (2012). Evaluation of formaldehyde emission from different types of wood-based panels and flooring materials using different standard test methods. Building and Environment, 49: 86-96, https://doi.org/10.1016/j.buildenv.2011.09.011.

[18] Zihao Zheng, Hemiao Zhang, Hua Qian, Jingguang Li, Tao Yu, Cong Liu (2022). Emission characteristics of formaldehyde from natural gas combustion and effects of hood exhaust in Chinese kitchens. Science of The Total Environment, 838, Part 4, 156614. https://doi.org/10.1016/j.scitotenv., 156614.

[19] Jung, C., Abdelaziz Mahmoud, N. S., Al Qassimi, N., & Elsamanoudy, G. (2023). Preliminary Study on the Emission Dynamics of TVOC and Formaldehyde in Homes with Eco-Friendly Materials: Beyond Green Building. Buildings, 13(11): 2847. https://doi.org/10.3390/buildings13112847.