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Article

ANALYZING THE VARIATIONS IN POLLUTION LEVELS FOUND IN MEDICAL FACILITIES

Lucian COPOLOVICI[1,2*], Marinela BRENDEA[1], Andreea LUPITU[3], Flavia BORTES[2,3], Cristian MOISA[3], Dana COPOLOVICI[1]

[1]Faculty of Food Engineering, Tourism and Environmental Protection, Aurel Vlaicu University, 2 Elena Dragoi St., Arad, 310330, Romania
[2]Interdisciplinary Doctoral School of Aurel Vlaicu University, 2 Elena Dragoi St., Arad, 310330, Romania
[3]Institute for Interdisciplinary Research, 2 Elena Dragoi St., Arad, 310330, Romania
**Corresponding author: lucian.copolovici@uav.ro*

Abstract:

This study investigates indoor air quality (IAQ) in a small medical family doctor facility, focusing on particulate matter (PM_1, $PM_{2.5}$, PM_{10}), formaldehyde, and total volatile organic compounds (TVOCs). Over five days, measurements revealed that indoor pollutant levels often exceeded those outdoors, with PM concentrations increasing throughout the week due to indoor activities and inadequate ventilation. Formaldehyde levels ranged from 21 to 100 µg/m^3, peaking in the doctor's office on Thursdays and Fridays and mid-week in other rooms. Outdoor TVOC levels were low and stable, while indoor levels were highest in the treatment room and doctor's office. These findings underscore the need for effective IAQ management to ensure a healthy environment for patients and healthcare workers.

Keywords: Indoor pollution, total volatile organic compounds, particulate matter, formaldehyde, medical office.

INTRODUCTION

Recent studies on human exposure to indoor air pollution have shown that indoor environments can be at least twice as polluted as outdoor ones (González-Martín et al., 2021). In fact, the air on a moderately busy urban street could be cleaner than the air inside a living room (Zhu et al., 2021). Traditionally, indoor air pollution has received much less attention than outdoor air pollution, particularly in heavily industrialized or high-traffic areas (Saraga et al., 2024). However, the risks associated with long-term exposure to indoor air pollution have become more apparent in recent years (Tran et al., 2020). This is because buildings are increasingly sealed off from the outside environment to save on heating and cooling costs. Many buildings now rely entirely on mechanical ventilation, which recirculates indoor air with minimal dilution from outside air, resulting in a buildup of indoor pollutants (Marć et al., 2018). A recent commission report estimated that nearly 3 billion people worldwide are exposed daily to poor indoor air quality (IAQ) due to using solid fuels for cooking, heating, and lighting (Fang et al., 1998).

Indoor pollutant levels can be up to five times, or even 100 times, higher than outdoor pollutant levels, raising significant concerns given that the average individual spends approximately 90% of their time indoors (Ibrahim et al., 2022). Efficient air quality management in hospitals or other medical institutions is essential for preventing infections, especially for patients with weakened immune systems (Śmiełowska et al., 2017). Additionally, it is necessary for maintaining healthcare workers' health, productivity, and well-being (Ibrahim et al., 2022). Various aspects of healthcare facility design, including spatial dimensions, building envelope design, ventilation system design, and outdoor air intake, have been demonstrated to influence indoor air quality (IAQ).

The management of hospital hygiene has a significant role in determining indoor air quality (IAQ) by impacting the levels of indoor pollutants. Inconsistent cleaning methods lead to accumulating particulate matter (PM), which can be stirred up again as building inhabitants walk around, especially when PM levels are high (Yau and Chew, 2009). Engaging in hospital-specific activities and therapies, such as handwashing in sinks, utilizing medicinal sprays, administering nebulization therapy, changing beds, and completing housekeeping tasks, has been demonstrated to impact the concentration of particles and total volatile organic compounds in indoor air (Pereira et al., 2017). Furthermore, using electronic devices such as copiers, printers, and computers for hospital administration may emit benzene, toluene, ethylbenzene, and xylene (BTEX) compounds, which are highly toxic to hospital occupants (Elke et al., 1998). Formaldehyde is extensively utilized in medical settings globally, primarily for tissue preservation in pathology laboratories, as a sterilizing agent and disinfectant (Ghasemkhani et al., 2005). Possible formaldehyde sources in the employment environment's nonexposed sections include pressed wood products, adhesives, varnishes, furniture, and carpets (Salthammer et al., 2010).

This study aims to determine total volatile organic compounds (TVOCs), formaldehyde, and particulate matter levels in different rooms of a small medical family doctor facility.

MATERIALS AND METHODS

The samples were collected from a family medicine practice (located in Bistrita, Romania) with four rooms: file room, waiting room, treatment room, doctor's office, and outdoors. The Dienmern DM 106 multiparameter analyzer (China) was used to measure the concentrations of total volatile organic compounds, formaldehyde, as well as suspended particles of PM_1, $PM_{2.5}$, and PM_{10}, following the same procedure as in (Tepeneu et al., 2023). The samples were collected over five days, from June 10-14, 2024, with a minimum of 4 daily determinations. Statistical analysis of the data was performed using GraphPad Prism version 10.3.0.

RESULTS AND DISCUSSIONS

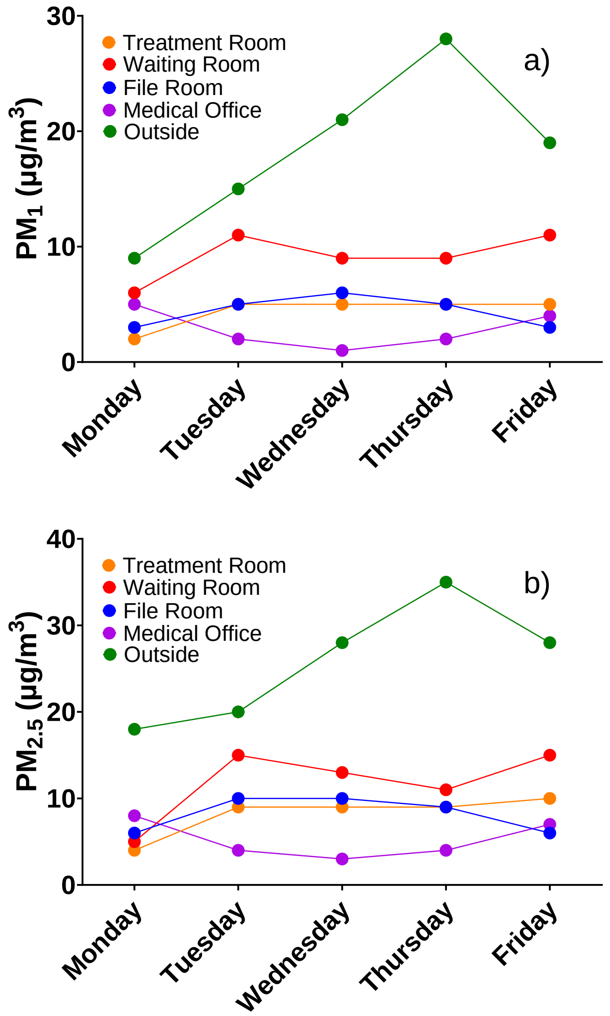
The concentrations of suspended particles determined over one week are presented in Figure 1. The data indicate particulate matter (PM) levels in the air, categorized into different sizes: PM 1, PM 2.5, and PM 10. These measurements provide insight into air quality within the medical facility over the specified period.

Regarding the values obtained for the outdoor air, it was found that the concentrations are at the limit of the maximum allowable value. This high concentration is understandable given the context of the measurements. The sampling was conducted right in front of the medical office, which is located in a heavily trafficked area. High traffic typically results in elevated levels of air pollutants, including particulate matter, due to vehicle emissions. Thus, the outdoor air quality around the medical office is significantly influenced by the vehicular activity in the vicinity.

For the indoor air, an increase in concentrations of suspended particles is observed during the week for three rooms: the file room, waiting room, and treatment room. This trend suggests that particulate matter accumulates over time, potentially due to indoor activities, human presence, and possibly inadequate ventilation or filtration systems that fail to remove the particles from the indoor environment effectively. It is important to note that various activities within these rooms, such as patient interactions, cleaning, and treatment procedures, can contribute to generating and suspending particulate matter.

In contrast, the concentrations of suspended particles in the doctor's office show a different pattern. Here, the concentrations are higher, specifically on Monday and Friday. This variation might be attributed to several factors. One plausible explanation is the influx of air from the outside, which might be more pronounced these days due to increased opening of doors and windows or higher patient turnover. Additionally, the doctor's office might experience specific activities on these days that contribute to the higher particulate matter levels, such as particular treatments or cleaning routines.

Indeed, the ratio between the indoor and outdoor concentration values for particulate matter is less than one for all three fractions (PM 1, PM 2.5, and PM 10). This indicates that indoor air has lower concentrations of suspended particles than outdoor air (Fan et al., 2020). While this is generally positive, as it suggests some level of protection from outdoor pollution, it also highlights the facility's need for effective air quality management. The fact that outdoor conditions influence indoor air quality underscores the importance of proper ventilation and filtration systems to minimize the infiltration of outdoor pollutants and maintain a healthy indoor environment (Zhou and Yang, 2022).



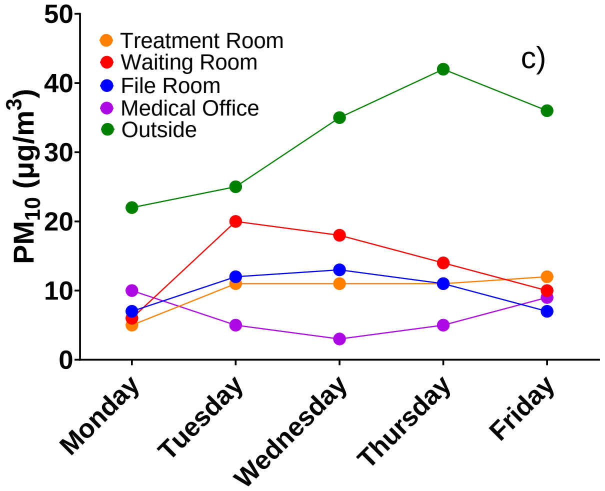


Figure 1. Daily variations in PM_1 (a), $PM_{2.5}$ (b), and PM_{10} (c) concentrations over one-week measurements in 4 different rooms and outside.

The data revealed a distinct pattern across the four examined rooms within the medical facility in the context of formaldehyde concentrations. Formaldehyde is classified as a Group B2 probable human carcinogen under the Integrated Risk Information System (IRIS) of the United States Environmental Protection Agency (EPA), indicating its potential health risks, including respiratory ailments, skin irritation, and carcinogenicity with prolonged exposure. Figure 2 provides a graphical representation of these variations, elucidating the temporal dynamics of formaldehyde concentrations within the facility and pinpointing specific periods of elevated levels.

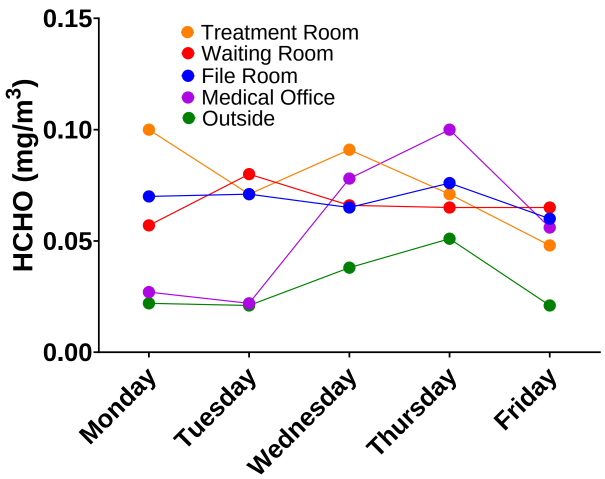


Figure 2. Daily variations in formaldehyde concentration over one-week measurements in 4 different rooms and outside.

The formaldehyde concentrations measured within the medical facility ranged from 21 to 100 μg/m^3. Notably, this upper limit is at the threshold of 100 μg/m^3, the maximum allowable concentration for public-use facilities, underscoring the necessity for vigilant monitoring and mitigation strategies to safeguard occupant health. Disaggregating the data by room reveals varied temporal patterns in formaldehyde concentrations, with the doctor's office exhibiting higher concentrations on Thursday and Friday. This temporal variation could be attributed to specific end-of-week activities or increased utilization of materials and products that emit formaldehyde, such as certain cleaning agents, disinfectants, or medical supplies used more intensively. In contrast, the file, waiting, and treatment rooms generally showed higher formaldehyde levels mid-week. This mid-week increase might result from cumulative daily activities, augmented patient interactions, and routine maintenance procedures that involve formaldehyde-emitting substances. The formaldehyde concentration outside the building remained constant at approximately 30 μg/m^3, contrasting with the fluctuating indoor levels and highlighting the significant influence of indoor sources and activities on formaldehyde concentrations within the facility. The consistently lower outdoor concentration serves as a baseline, reinforcing the need to address indoor pollution sources.

The concentration of total volatile organic compounds (TVOCs) outside is consistently very low and remains stable throughout the measurement period. This stability indicates minimal variation in outdoor sources of TVOCs during the monitoring period, possibly due to fewer volatile organic compound emissions near the medical facility (Figure 3).

In contrast, the concentration of volatile organic compounds within the different rooms of the medical facility shows significant variability. This variability can be attributed to indoor activities and sources that emit these compounds. Specifically, in the treatment room and the doctor's office, the TVOC concentrations are notably higher. This level elevation is likely due to using and administering various medications and medical procedures that release volatile organic compounds. These activities include disinfectants, cleaning agents, and other chemical products commonly used in medical treatments and patient care.

This distinction between the stable, low outdoor concentrations and the variable, higher indoor concentrations highlight the impact of indoor sources on air quality within the medical facility.

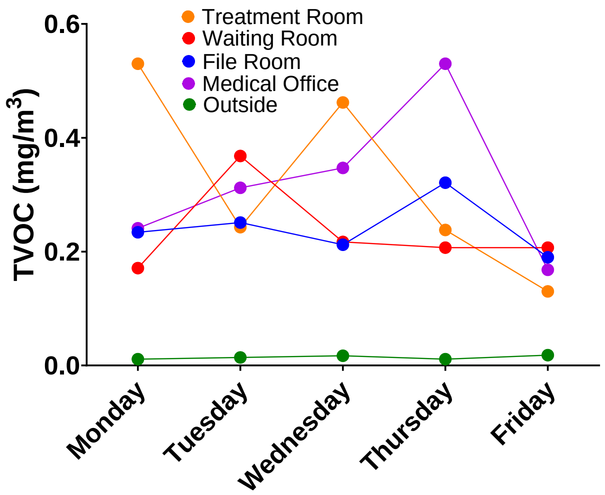


Figure 3. Daily variations in TVOC concentrations over one-week measurements in 4 rooms and outside.

It underscores the need for targeted air quality management practices, such as proper ventilation and low-emission products, to mitigate the impact of volatile organic compounds on indoor air quality and ensure a safe environment for patients and healthcare providers.

To decrease the levels of particulate matter and formaldehyde in the medical facility, a multifaceted approach is necessary. For particulate matter, enhancing the ventilation system by incorporating HEPA filters, increasing outdoor air intake, and using portable air purifiers can significantly reduce airborne particles. Wet cleaning techniques and regular maintenance of HVAC systems are essential to prevent the resuspension of settled dust and ensure efficient air circulation. Minimizing activities that generate particulate matter during peak occupancy times and safely storing materials that emit particulates can further mitigate exposure. For formaldehyde reduction, source control is critical, including replacing formaldehyde-emitting materials with low-emission alternatives and limiting the use of formaldehyde-containing products. Improved ventilation, particularly by increasing air exchange rates and installing dedicated exhaust systems in high-use areas, helps remove formaldehyde from indoor air. Additionally, the use of air purification technologies like activated carbon filters and photocatalytic oxidation systems can effectively lower formaldehyde concentrations.

CONCLUSIONS

This study highlights the critical need for effective air quality management in a small medical family doctor facility, where indoor pollutant levels, including particulate matter (PM_1, $PM_{2.5}$, PM_{10}), formaldehyde, and total volatile organic compounds (TVOCs), often exceed outdoor levels. Measurements showed that PM concentrations increased indoors throughout the week, particularly in the file room, waiting room, and treatment room, likely due to indoor activities and insufficient ventilation. Formaldehyde levels ranged from 21 to 100 µg/m³, peaking in the doctor's office on Thursdays and Fridays and mid-week in other rooms, indicating the impact of specific activities and materials such as the use of formaldehyde-containing disinfectants, and increased operation of office equipment like photocopiers and printers. While outdoor TVOC levels remained low and stable, indoor concentrations were highest in the treatment room and doctor's office, underscoring the need for targeted interventions to mitigate indoor pollution and ensure a safe environment for patients and healthcare providers.

REFERENCES

Elke, K., Jermann, E., Begerow, J., Dunemann, L., 1998. Determination of benzene, toluene, ethylbenzene and xylenes in indoor air at environmental levels using diffusive samplers in combination with headspace solid-phase microextraction and high-resolution gas chromatography–flame ionization detection. Journal of Chromatography A 826, 191-200.

Fan, H., Zhao, C., Yang, Y., 2020. A comprehensive analysis of the spatio-temporal variation of urban air pollution in China during 2014–2018. Atmospheric Environment 220, 117066.

Fang, L., Clausen, G., Fanger, P.O., 1998. Impact of Temperature and Humidity on the Perception of Indoor Air Quality. Indoor Air 8, 80-90.

Ghasemkhani, M., Jahanpeyma, F., Azam, K., 2005. Formaldehyde Exposure in Some Educational Hospitals of Tehran. Industrial Health 43, 703-707.

González-Martín, J., Kraakman, N.J.R., Pérez, C., Lebrero, R., Muñoz, R., 2021. A state–of–the-art review on indoor air pollution and strategies for indoor air pollution control. Chemosphere 262, 128376.

Ibrahim, F., Samsudin, E.Z., Ishak, A.R., Sathasivam, J., 2022. Hospital indoor air quality and its relationships with building design, building operation, and occupant-related factors: A mini-review. Frontiers in Public Health 10.

Marć, M., Śmiełowska, M., Namieśnik, J., Zabiegała, B., 2018. Indoor air quality of everyday use spaces dedicated to specific purposes—a review. Environmental Science and Pollution Research 25, 2065-2082.

Pereira, M.L., Knibbs, L.D., He, C., Grzybowski, P., Johnson, G.R., Huffman, J.A., Bell, S.C., Wainwright, C.E., Matte, D.L., Dominski, F.H., Andrade, A., Morawska, L., 2017. Sources and dynamics of fluorescent particles in hospitals. Indoor Air 27, 988-1000.

Salthammer, T., Mentese, S., Marutzky, R., 2010. Formaldehyde in the Indoor Environment. Chemical Reviews 110, 2536-2572.

Saraga, D., Duarte, R.M.B.O., Manousakas, M.-I., Maggos, T., Tobler, A., Querol, X., 2024. From outdoor to indoor air pollution source apportionment: Answers to ten challenging questions. TrAC Trends in Analytical Chemistry 178, 117821.

Śmiełowska, M., Marć, M., Zabiegała, B., 2017. Indoor air quality in public utility environments—a review. Environmental Science and Pollution Research 24, 11166-11176.

Tepeneu, A., Lupitu, A., Surdea-Blaga, T., Moisa, C., Chambre, D., Copolovici, D.M., Copolovici, L., 2023. Variability of Air

Pollutants in the Indoor Air of a General Store, Applied Sciences.

Tran, V.V., Park, D., Lee, Y.-C., 2020. Indoor Air Pollution, Related Human Diseases, and Recent Trends in the Control and Improvement of Indoor Air Quality, International Journal of Environmental Research and Public Health.

Yau, Y.H., Chew, B.T., 2009. Thermal comfort study of hospital workers in Malaysia. Indoor Air 19, 500-510.

Zhou, Y., Yang, G., 2022. Real-time monitoring of pollutants in occupied indoor environments: A pilot study of a hospital in China. Journal of Building Engineering 59, 105105.

Zhu, L., Ranasinghe, D., Chamecki, M., Brown, M.J., Paulson, S.E., 2021. Clean air in cities: Impact of the layout of buildings in urban areas on pedestrian exposure to ultrafine particles from traffic. Atmospheric Environment 252, 118267.

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