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Indoor Air Quality in the Bedroom of a Single-Family House—A Case Study

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Abstract: People spend nearly 1/3 of their lives in bedrooms. Moreover, the greatest part of this time is spent in lack of awareness, so it is important to maintain suitable conditions in these areas, including air quality. In non-ventilated bedrooms, people may have trouble falling asleep, may not be resting enough during sleep, and they can wake up tired. This affects their well-being and behavior throughout the next day. Indoor air quality measurements were carried out in a single-family home bedroom. The measurements were made in unsealed windows. In the bedroom under examination, where people stay only during the night and where the door is always open and air is constantly being renewed, the carbon dioxide concentration during the night exceeded the permissible standard—1000 ppm.

Keywords: indoor air quality; microclimate; CO_2 concentration; IAQ in bedroom; single-family house

1. Introduction

For almost a whole day, man is in confined spaces. For almost a whole day, man is in an artificial atmosphere, often not responding to his needs and inconsistent with the norms [1–5]. Poor indoor air quality in light of research in various rooms has been presented by publications [6–8]. People return home after work and go to sleep at night. That is why good quality of air in bedrooms is very important [9–15].

In bedrooms in Poland, the most common type of ventilation is natural ventilation; it occurs in 82.5% of households [7].

The quality of indoor air in bedrooms is of great importance not only for better quality of sleep [11,13,15] but also for better quality of life [9,16].

This study on air quality in the bedroom aimed at presenting the values of carbon dioxide concentration in the analyzed room. The study also aimed at making a comparison of these values with the values given by other authors in the literature and providing an indication of the possibilities to improve the quality of air in bedrooms.

2. Materials and Methods

Carbon dioxide concentration tests were conducted in a detached house built in the 1980s (Figure 1). Window joinery was replaced in 2006 with a new, tight one and the window complex was enhanced with micro-ventilation (triple-trained U = 0.76 W/m^{2}K). The building only had only natural ventilation. The duration of the measurements was eight hours.

The source of carbon dioxide was only people—two adults. The bedroom had a door that was mounted without a threshold at a height of 2 cm from the floor. The bedroom's volume was 45 m^3.

The measurements were carried out continuously from 9:30 P.M. to 5:30 A.M. All measurements were made in four variants: Series I—closed windows; Series II—unsealed windows; Series III—windows ajar; Series IV—open windows.

For the measurements of temperature, humidity, and CO_2 concentration, an internal air quality meter Testo435-4 was used with an air quality probe. During all the measurements, the probe was located 0.4 m above the floor (as recommended by ASHRAE 2013 [2]). The IAQ (indoor air quality) probe was set 2 m from the source (person), 3m from the window, and 4 m from the open door. The dimensions of the rooms were measured with a Bosch DLE 70. Instrument parameters are given in publications [7,17].



Figure 1. Concentration of carbon dioxide in a bedroom (photograph by Wojciech Fiedoruk).

3. Results

Figure 2 presents the results of measurements of carbon dioxide concentration (one series of the measurements). The concentration of carbon dioxide was from 462 to 1429 ppm at an air temperature in the range of 18.5 to 23.3 °C and relative humidity in the range of 57.0 to 73.1%; at an atmospheric pressure of 1000 Pa, the CO_2 concentration background was 368–391 ppm.

The measurement of the carbon dioxide concentration was affected by an error in the range of 0.05% to 12.84%, and the relative humidity measurement was subject to an error of 0.01% to 0.15%. The calculation of errors was made in accordance with the literature [18,19]. The error bars are marked in Figure 2.

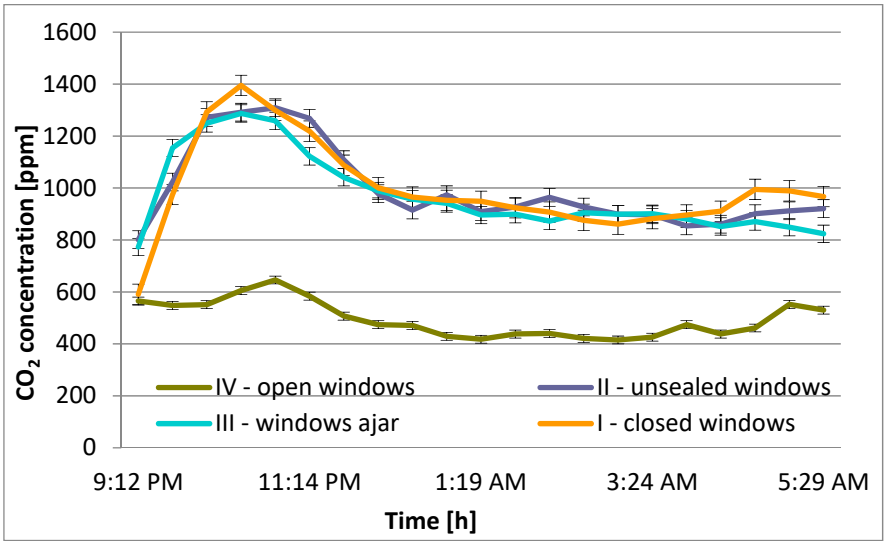


Figure 2. Concentration of carbon dioxide in the bedroom (own study).

4. Discussion

The relative humidity of the air in the bedroom and the temperature value of the air were in the range of standard values [1–5].

The values of carbon dioxide concentration in the rooms periodically exceeded the minimum hygienic value, i.e., 1000 ppm [1–5]. In the bedroom, the concentration of carbon dioxide until midnight increased to a maximum value of 1429 ppm (Figure 2); then, within two hours, it dropped to the value of around 1000 ppm, and in the subsequent part of the research fluctuated around this value. At different times of sleep, a person breathes with a varying intensity.

The measurement results were much better than those described in the literature [9,11,13,15,16,20].

5. Conclusions

In the bedroom under examination, where people only stay during the night, where the door is always open, and air is constantly being renewed, the carbon dioxide concentration during the night exceeded the permissible standard—1000 ppm [1–5].

A half-measure to improve the parameters of indoor air quality is the leakage of windows, regardless of weather conditions. Nothing can replace the periodic intensive ventilation of rooms in a building that does not have mechanical ventilation.

The presented measurement results indicate how important the quality of indoor air is in rooms such as bedrooms.

It is necessary to develop national standards to establish air parameters in residential buildings. This paper could be a reference for decision makers and designers when they choose appropriate ventilation types in buildings in order to meet good air quality targets.

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References

1. ASHRAE. *Standard 62-1989, Ventilation for acceptable Indoor Air Quality*; ASHRAE: Atlanta, GA, USA, 1989.
2. ASHRAE. *Thermal Environmental Conditions for Human Occupancy ANSI/ASHRAE Standard*; ASHRAE: Atlanta, GA, USA, 2013.
3. ASH American Society of Heating. *Refrigerating and Air-Conditioning Engineers—Guidelines for Design and Constructions of Health Care Facilities*; ASH American Society of Heating: Atlanta, GA, USA, 2006.
4. PN-EN 13779:2008 Ventilation of residential buildings. Requirements for the properties of ventilation and air conditioning.
5. WHO. *Air Quality Guidelines for Europe*, 2nd ed.; European Series, No. 91; WHO Regional Office for Europe Copenhagen: København, Danmark, 2000.
6. Chludzinska, M.; Bogdan, A. The effect of temperature and direction of airflow from the personalised ventilation on occupants' thermal sensations in office areas. *Build. Environ.* **2015**, *85*, 277–286, doi:10.1016/j.buildenv.2014.11.023.
7. Gładyszewska-Fiedoruk, K. Correlation of humidity and temperature in conference rooms—Preliminary tests. *E3S Web Conf.* **2018**, *49*, 00032, doi:10.1051/e3sconf/20184900032.
8. Uścinowicz, P.; Chludzinska, M.; Bogdan, A. Thermal environment conditions in Polish operating rooms. *Build. Environ.* **2015**, *94*, 296–304, doi:10.1016/j.buildenv.2015.08.003.
9. Bekö, G.; Lund, T.; Nors, F.; Toftum, J.; Clausen, G. Ventilation rates in the bedrooms of 500 Danish children. *Build. Environ.* **2010**, *45*, 2289–2295, doi:10.1016/j.buildenv.2010.04.014.
10. Brągoszewska, E.; Biedroń, I. Indoor Air Quality and Potential Health Risk Impacts of Exposure to Antibiotic Resistant Bacteria in an Office Rooms in Southern Poland. *Int. J. Environ. Res. Public Health* **2018**, *15*, 2604, doi:10.3390/ijerph15112604.

11. Lan, L.; Pan, L.; Lian, Z.; Huang, H.; Lin, Y. Experimental study on thermal comfort of sleeping people at different air temperatures. *Build. Environ.* **2014**, *73*, 24–31, doi:10.1016/j.buildenv.2013.11.024.
12. Molina, F.Q.; Yaguana, D.B. Indoor Environmental Quality of Urban Residential Buildings in Cuenca—Ecuador: Comfort Standard. *Buildings* **2018**, *8*, 90, doi:10.3390/buildings8070090.
13. Sekhar, S.C.; Goh, S.E. Thermal comfort and IAQ characteristics of naturally/mechanically ventilated and air-conditioned bedrooms in a hot and humid climate. *Build. and Environ.* **2011**, *46*, 1905–1916, doi:10.1016/j.buildenv.2011.03.012.
14. Verhaeghe, G. Self-Portrait in Bed. A Case Study of Carlo Mollino's 'Bedroom for a Farmhouse in the Rice Fields'. *Proceedings* **2017**, *1*, 894, doi:10.3390/proceedings1090894.
15. Wong, N.H.; Huang, B. Comparative study of the indoor air quality of naturally ventilated and airconditioned bedrooms of residential building in Singapore. *Build. Environ.* **2004**, *39*, 1115–1123, doi:10.1016/j.buildenv.2004.01.024.
16. Lin, Z.; Deng, S. A questionnaire survey on sleeping thermal environment and bedroom air conditioning in high-rise residences in Hong Kong. *Energy Build.* **2006**, *38*, 1302–1307, doi:10.1016/j.enbuild.2006.04.004.
17. Gładyszewska-Fiedoruk, K.; Jachimowicz, S. Analysis of carbon dioxide in Kindergartens in Poland. In Proceedings of the 10th International Conference Environmental Engineering, Vilnius, Lithuania, 27–28 April 2017. doi:10.3846/enviro.2017.022.
18. Teleszewski, T.J. Experimental investigation of the kinetic energy correction factor in pipe flow, E3S. *Web Conf.* **2018**, *44*, 00177, doi:10.1051/e3sconf/20184400177.
19. Teleszewski, T.J.; Sorko, S.A. Effect of viscous dissipation on forced convection for laminar flow through a straight regular polygonal duct using BEM method. *Int. J. Numeri. Methods Heat Fluid Flow* **2018**, *28*, 220–238, doi:10.1108/HFF-09-2017-0371.
20. Alfelali, M.; Khandaker, G. Infectious causes of sudden infant death syndrome. *Pediatric Respir. Rev.* **2014**, *15*, 307–311, doi:10.1016/j.prrv.2014.09.004.



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