

Indoor Air Quality in Office Buildings – experimental investigation

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Indoor Air Quality in Office Buildings – experimental investigation

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1. Introduction

- Common problems: the correlation of IAQ and health problems, the required number of air changes regarding mechanical ventilation and the possible energy savings and natural ventilation direction.
- Americans spend 90% of their time indoors [1].
- Natural ventilation contributes to energy savings, with about 40% lower energy costs comparing to an air-conditioned building [2].
- Multi-criteria analysis that could lead to the optimal solution between lower ventilation rates and desirable IAQ.

[1] United States Environmental Protection Agency, Healthy buildings, healthy people: A vision for the 21st century, Report No. EPA 402-K-01-003, 2001, US

[2] Allocca, C., Chen, Q., and Glicksman, L. R., Design analysis of single-sided natural ventilation, *Energy and Buildings*, 35 (2003), 8, pp. 785–795



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2. Standards regarding IEQ

- SRPS EN 15251:2010
- ISO 7730
- ASHRAE Standard 55
- ASHRAE Standard 62.1
- Etc.



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2.1. SRPS EN 15251:2010 – Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics

- Method based on person and building component, Method based on ventilation rate per person or per m² floor area, and Recommended values of CO₂ for energy calculation.
- The ventilation rates for given occupants and building's emissions are given in the standard as a function of the building category. For category II, temperature range for heating is between 20 and 25°C, and recommended airflow per person is 7 l/s/pers and 0,7 l/s/m² for low polluting building. Expected percentage of dissatisfied is 20. Corresponding CO₂ above outdoors for energy calculation is 500 ppm for category II.



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2.2. ISO 7730 – Moderate thermal environments – Determination of the PMV and PPD indices and specification of the conditions for thermal comfort

- Determines the Predicted Mean Vote (PMV) and Predicted Percentage of Dissatisfied (PPD) as a function of the activity and clothing.
- The limits for the light, mainly sedentary activity during the winter period:
 - a) The operative temperature shall be between 20°C and 24°C. The vertical air temperature difference between head and ankle level shall be less than 3°C.
 - b) The relative humidity shall be between 30 and 70%



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2.3. ASHRAE Standard 55 – Thermal Environmental Conditions for Human Occupancy

- Defines the thermal environmental conditions for human occupancy.
- Describes the metabolic rate, clothing insulation, air temperature, radiant temperature, air speed, humidity and position of the measuring equipment.
- Operative temperature or PPD, PMV shall be measured or calculated at a height of 0,6 m level above the floor for seated occupants and at the 1,1 m level for standing occupants .



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2.4. ASHRAE Standard 62.1 – Ventilation for Acceptable IAQ

- Gives ventilation criteria for acceptable IAQ when the mechanical ventilation system is designed.
- Maximal allowed CO₂ concentration for offices, according to ASHRAE 62.1:2013 is 700ppm higher than outdoor air level. Typical CO₂ concentration level in outdoor air is between 300 and 500 ppm, so maximal recommended CO₂ concentration for offices is from 1000 to 1200 ppm.
- The CO₂ concentration level is not the only and the most representative criteria for IAQ.
- The allowed concentration should always be determined as the difference between indoor and outdoor concentration.



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3. Building and equipment description

- The measurements were done in Process Equipment Design Laboratory at Aristotle University Thessaloniki, during March 2015.
- IEQ, regarding air temperature, relative humidity and CO₂ concentration were measured in two representative offices.

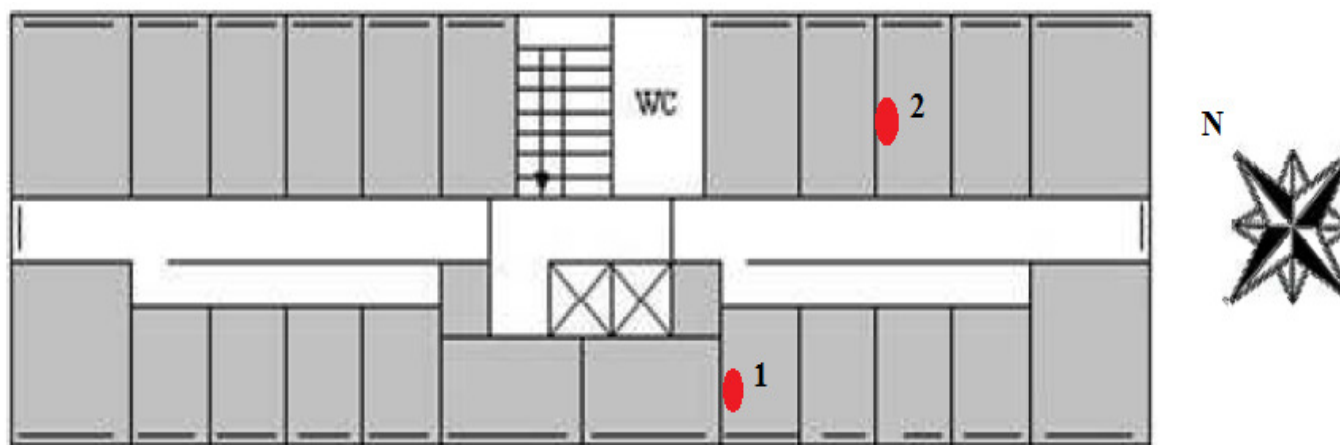
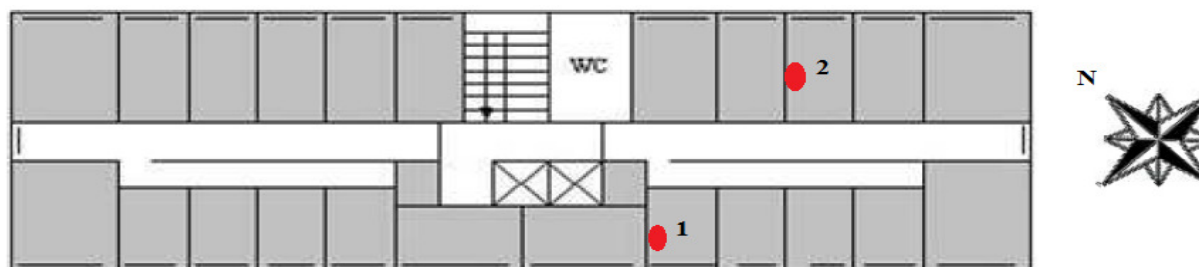


Figure 1. Process Equipment Design Laboratory at Aristotle University Thessaloniki

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3. Building and equipment description

- HOBO UX100-03 data loggers are used in both offices for temperature and relative humidity measurement and logging.
- In the office 2, the CO₂ concentration is measured, using Telaire 7001 manual CO₂ sensor.
- The HOBO data logger records temperature with $\pm 0,21\%$ accuracy and humidity within $\pm 3,5\%$ accuracy.
- The Telaire 7001 manual CO₂ sensor has a measurement range from 0 to 10000 ppm, with $\pm 5\%$ accuracy.



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4. Measurement results and discussion

Date	CO ₂ max [ppm]	CO ₂ min [ppm]	Time	Window	Door	People
9.3.2015.	1394		13:47	open	open	2
		991	12:15	closed	open	3
10.3.2015.	1025		13:44	open	closed	2
		564	10:09	open	open	1
11.3.2015.	1089		12:38	closed	closed	2
		513	9:50	closed	closed	0
12.3.2015.	692		14:15	closed	open	1
		403	10:15	open	open	0
13.3.2015	681		13	closed	closed	1
		480	9:50	closed	closed	1
16.3.2015.	1080		13:41	half closed	closed	3
		440	10	closed	closed	0
17.3.2015.	1406		13:17	closed	half closed	3
		470	10	open	closed	0
18.3.2015	930	433	10	closed	open	1
			14:30	closed	half closed	3
19.3.2015.	743	450	10	open	open	0
			13:44	closed	open	2
20.3.2015.	1023	402	9:45	closed	closed	0
			13:35	closed	closed	3

Table 1. Maximal and minimal CO₂ concentrations during two weeks in office 2



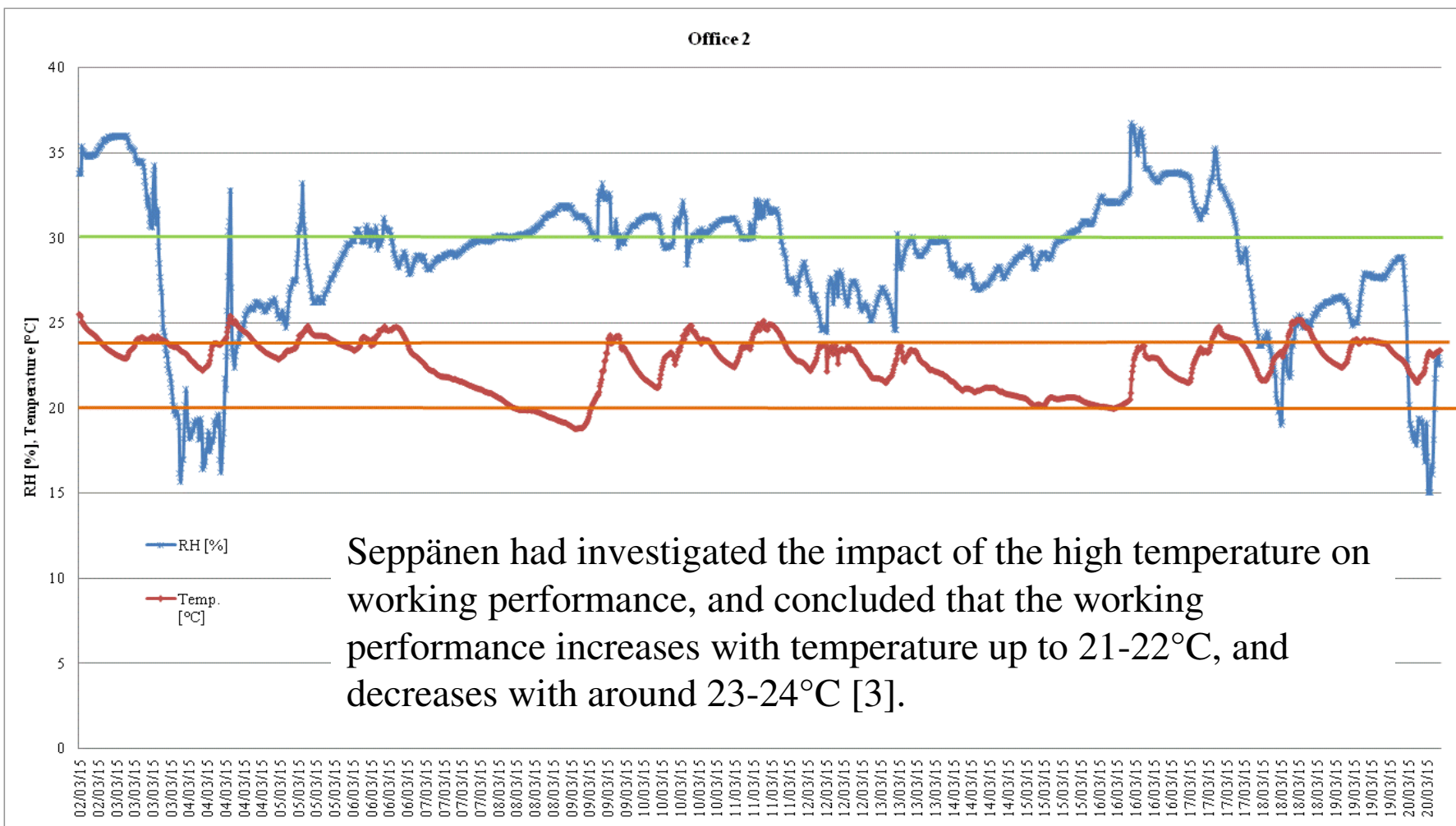
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4. Measurement results and discussion

- The biggest CO₂ concentration is recorded during the day when the window was not opened and the number of the people in the office was 3. In that period, the lack of working concentration and productivity was observed, together with some of people suffering headaches and a bad odor.
- The indoor air temperature was varying from 20,28°C to 25,09°C, depending on the window opening and the number of the people in the office. During most periods of time, the CO₂ concentration was slightly higher than recommended.
- Also, the relative humidity and the temperature are measured in this office, in a period from 02.03.2015 until 20.03.2015. with data logging every 15 minutes.
- The heating system in the University building is central, two-pipe system with radiators and with thermostatic valves.



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[3] Seppänen, O., Scientific basis for design of ventilation for health, productivity and good energy efficiency, *Proceedings, 11th Indoor Air Congress*, Copenhagen, Denmark, 2008, paper ID: 744



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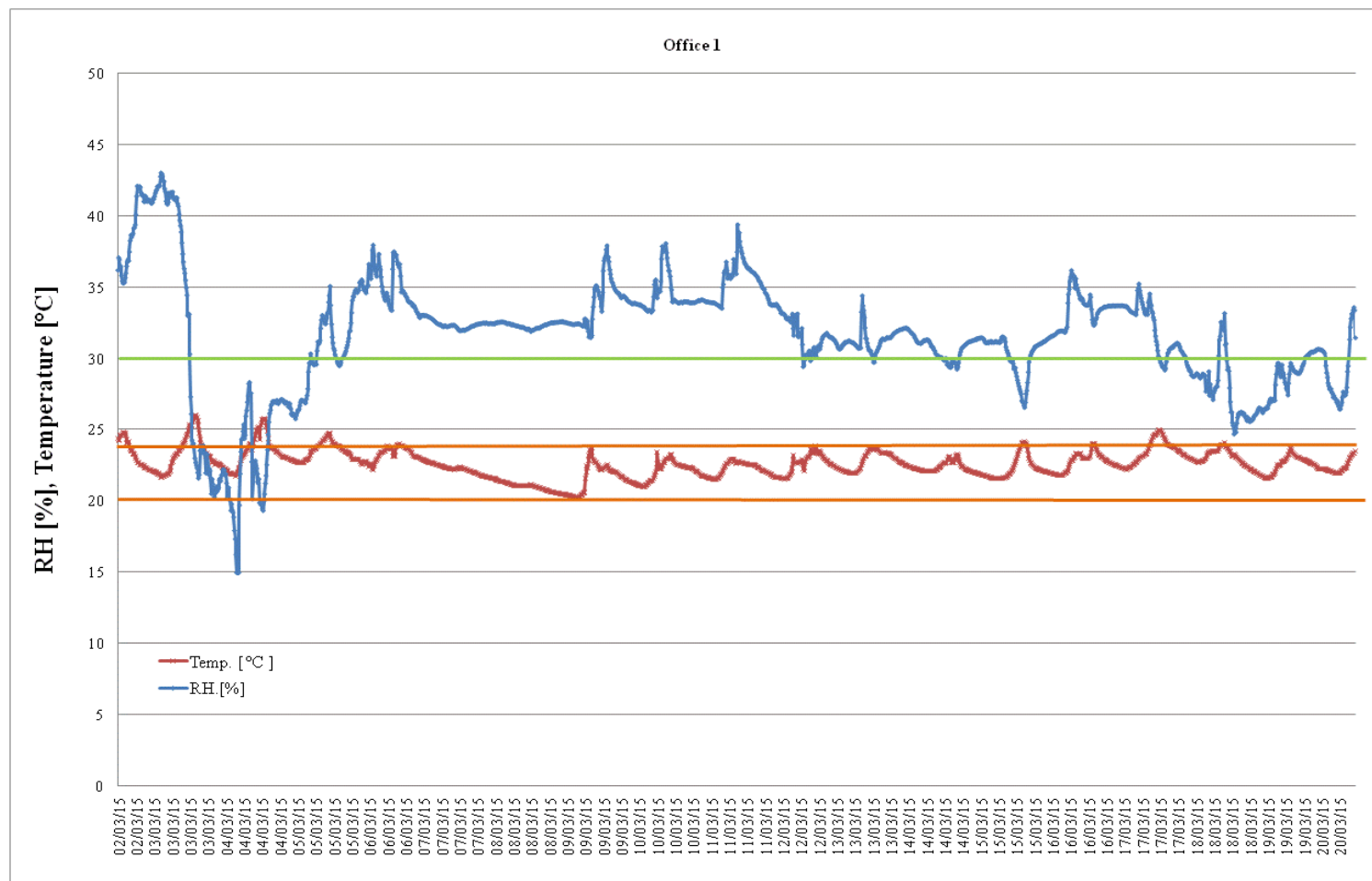
4. Measurement results and discussion

- From Figure 2. it can be seen that the temperatures are in the desired range for more than 75% of the time. Only 6,5% of the time, temperature was lower than 20°C, but still higher than 18°C. Around 18,5% of the time, the temperature was higher than 24°C, but it has never reached 26°C. These results are expected, having in mind the heating system with the thermostatic valves.
- More than 61% of the time, the relative humidity was lower than recommended 30%, and only 39% of the time, it stayed within the recommended boundaries. Around 49% of the time, the relative humidity was between 25% and 30%. This is clearly a result of overheating and of less ventilation than required. The lowest recorded value was RH=15%, and it was recorded at 8:15 a.m., in the period when the office was empty.
- During the working hours, from 10 a.m. till 2 p.m. the significant number of values, about 92%, was lower than minimal recommended value. During the only 8% of the working hours, the relative humidity was higher than 30%, and due to that, in a desired range.



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4. Measurement results and discussion



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- In office 1, the temperatures are in between the desired range in more than 92% of the time. Minimal recorded value is 20,27°C, and maximal value is 26°C. Du to that, only 8% of the time, the temperature was higher than 24, and lower than 26°C. The average temperature during the working hours was 23°C.
- Looking at the relative humidity, the situation in Office 1 is much better than in the Office 2; the relative humidity was in desired range in 75% of the time. During the working hours, the average value of relative humidity was RH=32%, and in the 76% of the time it was equal or higher than RH=30%. Minimal recorded value was RH=15%, and maximal RH=43%.



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5. Conclusions

- According to the previous results, it could be concluded that the IAQ, during the most of the working hours was not satisfying. Looking at the negative influence of low humidity on human's health, some authors were investigated the symptoms such as: dryness of the eyes and skin, dryness of the nasal mucous membrane [4]. It is stated that the low humidity influence increasing of bacterial, viral and other respiratory infection [4].
- The key problem in offices with natural ventilation in the winter period is low relative humidity and high CO₂ concentration levels, a rather limited ventilation.
- The control of IAQ indicators and appropriate ventilation is crucial for occupants' health and productivity and naturally also for conserving energy and reducing operational expenses having in mind the expenses of treatment and workers' absences. The decision about the appropriate ventilation rates should always take into account the anticipated benefits for occupants' health, rather than choosing the minimal rates for energy savings.

[4] Sunwoo, Y., Chou, C., Takeshita, J., Murakami, M., and Tochihara, Y., Physiological and subjective responses to low relative humidity, *Journal of physiological anthropology*, 25 (2006), 1, pp. 7–14



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Measurement in classroom at the Automatic control Department in Belgrade



Thank you for the attention!



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