Low Relative Humidity, a Problem or Not in Swedish Dwellings?

Theofanis Psomas, PhD
Postdoc Researcher

Despoina Teli, PhD
Associate Professor

Sarka Langer, PhD
Adjunct Professor

Paula Wahlgren, PhD
Associate Professor

ABSTRACT

The current research investigates the relative humidity conditions in Swedish dwellings (678 apartments and single-family houses), comparing measurements from the 2007/2008 BETSI-survey (heating season), with the recommendations of the EN 16798:2019. Analysis shows that 61.4% of the apartments and 29.8% of the single-family houses belong to Cats. 3 and 4, which correspond to moderate and low level of expectation, respectively (mainly due to low relative humidity). The problem is bigger for dwellings with smaller volume, higher ventilation rate and indoor temperature, constructed mainly after 1985.

INTRODUCTION

People spend a considerable amount of time indoors, especially at home. High quality indoor environment for residential buildings is essential for good health, high productivity and comfort (CEN 2019). Scientific research focuses mainly on the assessment of the indoor environment of dwellings in terms of thermal comfort and pollutant concentrations in association with different systems and controls, occupancy behaviors and health symptoms (Psomas et al. 2017; Langer and Bekö 2013). Another important quality factor for the dwellings, which influences health, stress response, sleep quality and well-being, is the level of humidity indoors (Wolkoff 2018; Derby et al. 2017).

Dry air is common in northern climates because air cannot hold the moisture and it condenses. However, hygrothermal analysis is not mandatory for dwellings and conducted mainly to prevent moisture damages, which is the main cause of building structure deterioration and poor environment ("dampness") in offices, schools and crawl spaces (CEN 2019; Alsmo 2016). Low relative humidity (RH) levels are associated with a number of respiratory infections and allergies and cause, among others, signs of dryness of nasal and laryngeal airways, dry hands and eye irritations (Arundel et al. 1986; Wolkoff 2018). A decrease in morbidity and mortality due to lethal viruses (e.g. influenza) and bacteria (also pathogens suspension) is probably the most beneficial output of an increase in RH from low to moderate levels (Alsmo 2016). Finally, RH works as fire risk indicator and low levels relate to static electricity complaints (Derby et al. 2017).

The current research investigates the RH conditions in Swedish dwellings, comparing measurements from the extensive 2007/2008 BETSI-survey (heating season) conducted by the National Board of Housing, Building and Planning (Boverket), with the recommendations of the state-of-the-art European Standard EN 16798:2019 (CEN 2019; Teli et al. 2018). The research also explores the association of the RH levels with building characteristics (building volume and construction age), the measured indoor air temperature and the ventilation rate.

Theofanis Psomas is a postdoc researcher in the Department of Architecture and Civil Engineering, Division of Building Services Engineering, Chalmers University of Technology, Sweden. **Despoina Teli** is an Associate Professor in Chalmers University of Technology, Sweden. **Sarka Langer** is an Adjunct Professor in Chalmers University and project manager in IVL Swedish Environmental Research Institute, Sweden. **Paula Wahlgren** is an Associate Professor in Chalmers University of Technology, Sweden.

METHODS AND MATERIALS

The current analysis refers to 678 dwellings (single-family houses and apartments; living rooms), monitored between October 2007 and April 2008 (2 weeks on average). The technical details of the BETSI-survey are presented in (Langer and Bekö 2013). Table 1 presents the RH recommendation limits for different categories and levels of expectation of the European Standard EN 16798:2019. Deviation percentage for every category is set to 3% (Psomas et al. 2018). Assessment period is the monitoring period for every dwelling. To determine if there are statistically significant differences between category medians, the Kruskal-Wallis test is used (p-value is adjusted by the Bonferroni correction).

Table 1. Recommended design criteria for relative humidity in occupied spaces*

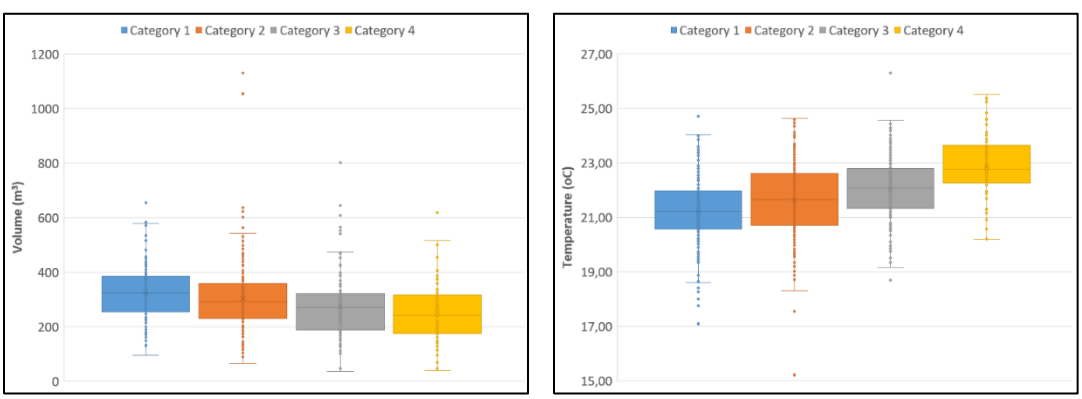
Category*	Level of expectation	Upper level for relative humidity (%)	Lower level for relative humidity (%)
I	High	50	30
II	Medium	60	25
III**	Moderate	70	20

* Spaces where humidity criteria are set by human occupancy. **Category IV: low level of expectation, no limits.

RESULTS

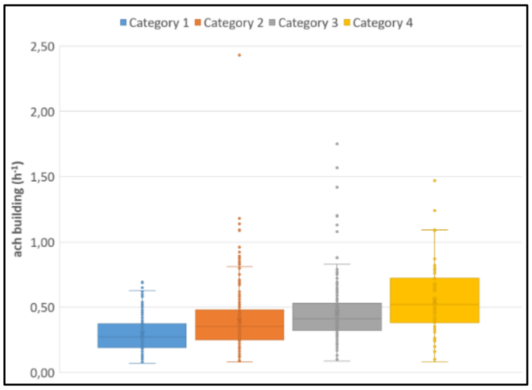
Analysis shows that 61.4% of the apartments and 29.8% of the single-family houses belong to Cats. 3 and 4, mainly due to low RH. Figure 1(a-c) presents the boxplot diagrams of the building volume (m^3), the average indoor air temperature (^oC) and the ventilation rate (h^{-1}), for the four RH assessment categories. On average, the increase of the volume of the dwelling tends to improve the indoor air quality in terms of RH. The median values of the boxplots are 135m^2 and 101m^2 for Cats. 1 and 4 respectively (average height of 2.4m). Mean and median values are close for the total of the analysis. A possible explanation is that the size of a dwelling correlated directly with the number of occupants and humidity supply through indoor activities. In addition, the decrease of the ventilation rate improves the indoor RH levels (low outdoor absolute humidity). The mean values are 0.29 (h^{-1}) and 0.55 (h^{-1}) for Cats. 1 and 4 respectively. The RH strongly related with air temperature. Increase of the average indoor temperature from 21.3^{o}C to 22.7^{o}C for Cats. 1 and 4 respectively, tends to degrade the indoor quality by lowering the RH. Most of the differences among the medians of the categories are statistically significant for the three examined parameters. Figure 1d presents the frequency bar chart of the construction age of the assessed dwellings, for four RH categories. Almost 50% of the recently built dwellings (after 1985) belong to Cats. 3 and 4, which correspond to moderate and low level of expectation, respectively.

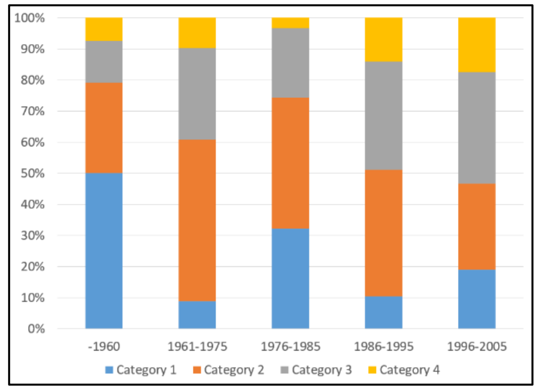
(a)



(b)

(c)





(d)

Figure 1 Boxplots for all the examined dwellings, for the four RH assessment categories, versus the (a) volume of the dwelling (m^3) (b) average indoor air temperature (^oC) and (c) ventilation rate (h^{-1}). Frequency bar chart, for the four RH assessment categories, of the examined dwelling per construction period (d). Statistical significance: a) Every non-adjacent category, b) Cat. I and II (*), Cat. II and III (*), Cat. III and IV (***) and every non-adjacent category and c) Cat. I and II (***), Cat. II and III (**) and every non-adjacent category. *: $p<0.05$, **: $p<0.005$, ***: $p<0.0005$.

CONCLUSIONS

Analysis concludes that low RH is a realistic problem in Swedish dwellings during the heating season. The problem is bigger for dwellings (after 1985) with smaller volume, higher ventilation rate and indoor temperature. Future work will identify differences between the examined dwellings through deeper statistical analysis and associations with other parameters such as HVAC systems, human behaviors (drying of clothes and others), outdoor conditions and health.

ACKNOWLEDGMENTS

This work received funding from "The Swedish Research Council-FORMAS" (project Nr. 2018-00698) and "The Swedish Energy Agency" (project Nr. 2018-006191).

REFERENCES

Alsmo, T., and C. Alsmo. 2016. A comparison of relative humidity between two Swedish buildings with different ventilation solutions. *Journal of Environmental Protection* 7:855–73.

Arundel, A.V., Sterling, E.M., Biggin, J.H., and T.D. Sterling. 1986. Indirect health effects of relative humidity in indoor environments. *Journal of Environmental Health Perspectives* 65:351–56.

CEN. 2019. ÖNORM EN 16798-1:2019, *Energy performance of buildings. Ventilation for buildings. Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics. Module M1-6*. Wien: Austrian Standards, International Standardization and Innovation.

Derby, M.M., Hamehkasi, M., Eckels, S., Hwang, G.M., Jones, B., Maghirang R., and D. Shulan. 2017. Update of the scientific evidence for specifying lower limit relative humidity levels for comfort, health, and indoor environmental quality in occupied spaces. *Journal of Science and Technology for the Built Environment* 23(1): 30–45.

Langer, S., and G. Bekö. 2013. Indoor air quality in the Swedish housing stock and its dependence on building characteristics. *Building and Environment* 69:44–54.

Psomas, T., Heiselberg, P., Lyme, T., and K. Duer. 2017. Automated roof window control system to address overheating on renovated houses: summertime assessment and intercomparison. *Journal of Energy and Buildings* 138:35–46.

Psomas, T., Heiselberg, P., Duer, K., and M.M. Andersen. 2018. Comparison and statistical analysis of long-term overheating indices applied on energy renovated dwellings in temperate climates. *Journal of Indoor and Built Environment* 27(3):423–35.

Teli, D., Langer, S., Ekberg, L., and J.O. Dalenbäck. 12-15, March 2018. Indoor temperature variations in Swedish households: implications for thermal comfort. The 9th International Cold Climate Conference. Kiruna, Sweden.

Wolkoff, P. 2018. Indoor air humidity, air quality, and health – An overview. *International Journal of Hygiene and Environmental Health* 221:376–90.