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Hygrothermal Analysis of Indoor Environment of Residential Prefabricated Buildings

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Abstract. Recent studies show that the relative humidity and the indoor air temperature constitute an important determinant of the quality of indoor air. Hygrothermal microclimate has a significant impact on occupant's health and their comfort. The study presents the results of experimental measurement of indoor air temperature and relative humidity in selected apartment in prefabricated panel house situated in Ostrava, Czechia. The contribution describes and analysis the relation between indoor air temperature [°C] and relative humidity [%] in this apartment. The experimental object is selected with respect to the housing stock in the Czech Republic. A third of the housing stock in the Czech Republic is composed of prefabricated panel houses. Regeneration and revitalization of these buildings were in the focus of interest during recent years. Building modifications, such as thermal insulation of building envelope or window replacement, lead to a significantly higher level of airtightness of these objects. Humidity and indoor air temperature are measured in 10-minute cycles for two periods. The values of temperature and humidity are measured for the non-heating and the heating season. The length of each experimental period is 30 days. The mean value of indoor air temperature is 22.21 °C and average relative humidity is 45.87% in the non-heating period. The values of 22.62 °C and 35.20% represent average values for the heating period. A slight increase of the average temperature of the indoor environment (+1.85%) is observed. The decrease of the relative humidity is evident at first glance. The relative humidity of the internal environment is approximately 10% lower in the heating period. Long-term decline of relative humidity below 30% brings many problems. It is necessary to take measures to increase of relative humidity in residential prefabricated building. The aquarium appears to be ineffective. The solution may be forced artificial ventilation or humidifiers.

1. Introduction

A number of interrelated parameters independently components, such as thermal-humidity microclimate, odours, aerosol microclimate, microbial microclimate or even acoustics microclimate, defines indoor environments. There are many health's problems associated with inadequate indoor air quality. A major impact on people has a hygrothermal microclimate. Regular and long-term stay in unsuitable conditions of indoor environment can bring a wide range of mental and physical problems, such tearing eyes, nose irritation, wheezing, coughs and frequent respiratory infections, skin itching, headaches, nausea or insomnia. The complex of these health problems is known as Sick Building Syndrome (SBS) [1-4]. Among the most common causes of the Sick Building Syndrome include inadequate ventilation, thermal discomfort, low or too high humidity, poor lighting, air pollution (particulate matter, microbiological contaminants or volatile organic compounds).

2. Hygrothermal microclimate

Hygrothermal microclimate is an essential part of indoor air quality (IAQ) constantly influenced by the heat and humidity flows. Hygrothermal microclimate is defined by three fundamental factors - indoor air temperature [°C], indoor relative humidity [%] and air velocity [m/s].

Hygrothermal microclimate is the still actual issue of building physics. Heat and moisture flows are defined by exterior climatic conditions, thermal properties of the building envelope and by internal sources of heat and water vapour. Airtightness of the building envelope also plays an important role [5]. The figure 1 illustrates comfort of the indoor environment in the context of hygrothermal microclimate [6]. Humidity of internal environment also plays an important role in terms of durability of structures. Too much moisture leads to the disintegration of finishes and deterioration of thermal insulation.

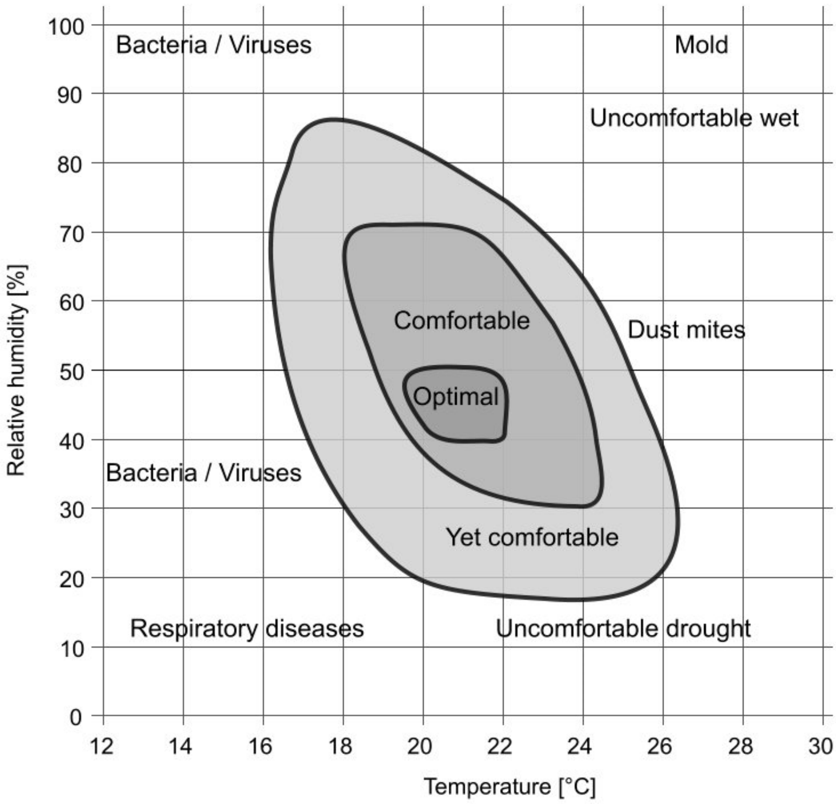

Figure 1. Comfort of the indoor environment in the context of hygrothermal microclimate [6]

The optimum interior temperature is between 20-22 °C. Temperature in the range 23-26 °C is considered as comfortable in the summer. An internal environment with a temperature between 18 and 24 ° C can be defined as a comfortable indoor environment [5]. Too high or low temperatures pose a serious hazard of human health. Too low temperatures can be one of the causes of the development of cardiovascular disease and death for people with weakened immune systems and the elderly [7]. Too high temperature overloads organism. Thermoregulatory processes are trying to maintain thermal balance. Performance decreases proportionally with increasing temperature. The cardiovascular system is more stressed in case of higher ambient temperatures. Sweating is typically a consequence for overheating of the body. High temperatures in the indoor environment evoke muscle cramps in the organism, which are caused by the loss of fluids and minerals. Too high temperatures in indoors are characterized by decrease of efficiency, thirsty, impaired coordination or by fatigue.

The optimum moisture of the internal environment fluctuates from 40 to 50%. The humidity in the range from 30 to 70% is still considered as a comfortable indoor environment. The humidity level of indoor air is affected by the operation of the household and the rate of ventilation. Humidity of in the indoor environment should not exceed 70% during the summer. In winter, the indoor relative humidity should not fall below 30%. Figure 2 illustrates the diagram of adverse health effects related to the relative humidity in the indoor environment [9].

The rise in humidity in the interior environment is typical for the unventilated or unused space. Today's buildings are characterized by high airtightness of the building envelope. Accumulation of humidity brings a wide range of problems. Too high values of relative humidity are associated with the occurrence of bacteria, viruses, fungi or mites. The higher indoor relative humidity is, the higher concentration of chemical pollutants in the air is. Concerns about excessive humidity and its prevention can lead to low humidity in indoors. However, overly dry air can cause the survival of certain types of viruses causing respiratory infections. Low humidity in the interior creates the potential for the creation of ozone [8, 9].

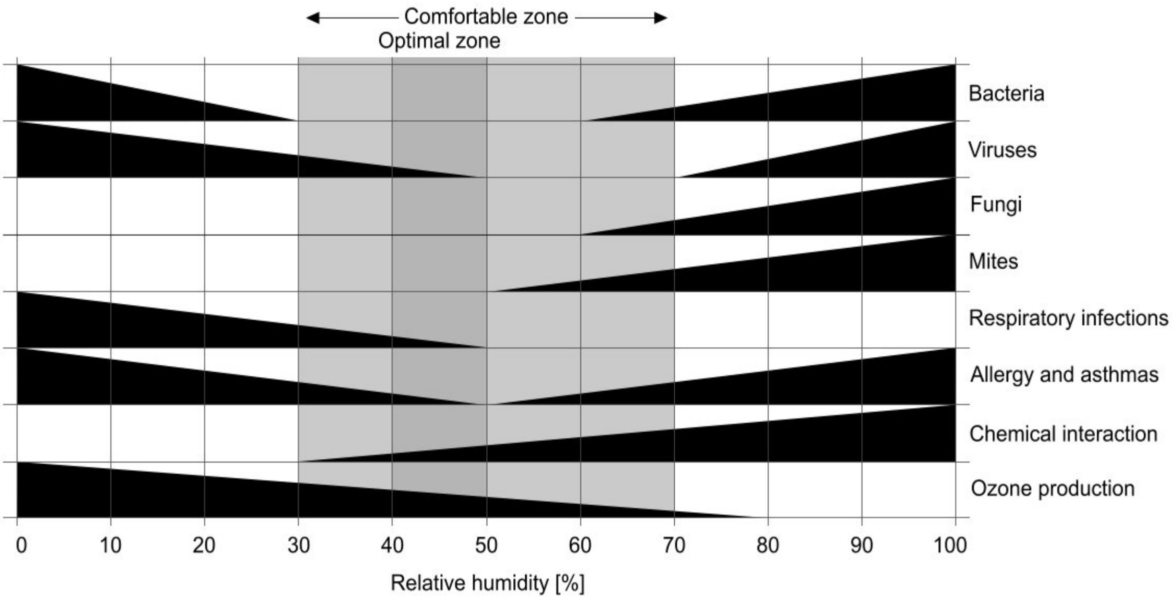

Figure 2. Comfort of the indoor environment in the context of hygrothermal microclimate [9]

3. Experimental measurements

This study is conducted in the apartment of prefabricated building in the city of Ostrava, Czech Republic. This location falls within the temperate climate zone of Central European. The mean outdoor air temperature is 9.1°C for October and 4.0°C for November in this locality. The average relative humidity of outside air is around 80% in that period (October – November).

The apartment is located on the second floor of the prefabricated panel house. Apartment features two rooms and sanitary core (kitchen, shared bathroom and toilet). The approximate floor area is 44 m^2. Conventional plate radiators heat the apartment. The apartment is normally used during the measurement. Two adult persons commonly live in the assessed apartment during the measurement. The condition and loading of moisture is normally like activities in the kitchen or bathroom. The aquarium (120 litres) is situated in the living room.

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The indoor air temperature and relative humidity is measured with wireless indoor sensor Elgato Eve Room (measurement accuracy: ±3% humidity, ±0.3 °C). The values of indoor air temperatures and relative humidity are measured in the 10-minutes cycles. The dimensions of the sensor are 79x79x32 mm. The measurement equipment is situated in the center of living room in the height of 1 500 mm above the floor. Data transfer is ensured by wireless technology - Bluetooth.

4. Results and discussions

4.1. Results for the non-heating period

Figure 3 shows measured indoor air temperature and relative humidity in apartment of residential buildings represented in 10-minute cycles values for non-heating period. The relative humidity is relatively constant in the optimal range (40-50% RH) throughout October. The mean value of relative humidity for the non-heating period is set 45.87% with standard deviation ±0.06%. The lowest measured value of relative humidity is 36.00%. The maximum obtained value of relative humidity equals to 63.00%. The range of relative humidity in October is 27%. The variance of indoor air temperature in the non-heating season is 15.60%.

Curve of temperatures is also shown in Figure 3. The mean value of indoor temperature for non-heating period is represented by value of 22.21 °C with standard error ±0.13 °C. The minimum value of indoor air temperature is 20.52 °C and the maximum value is 25.76 °C. The range value is 5.24 °C. Dispersion of the measured values from the mean value is equal to 0.73.

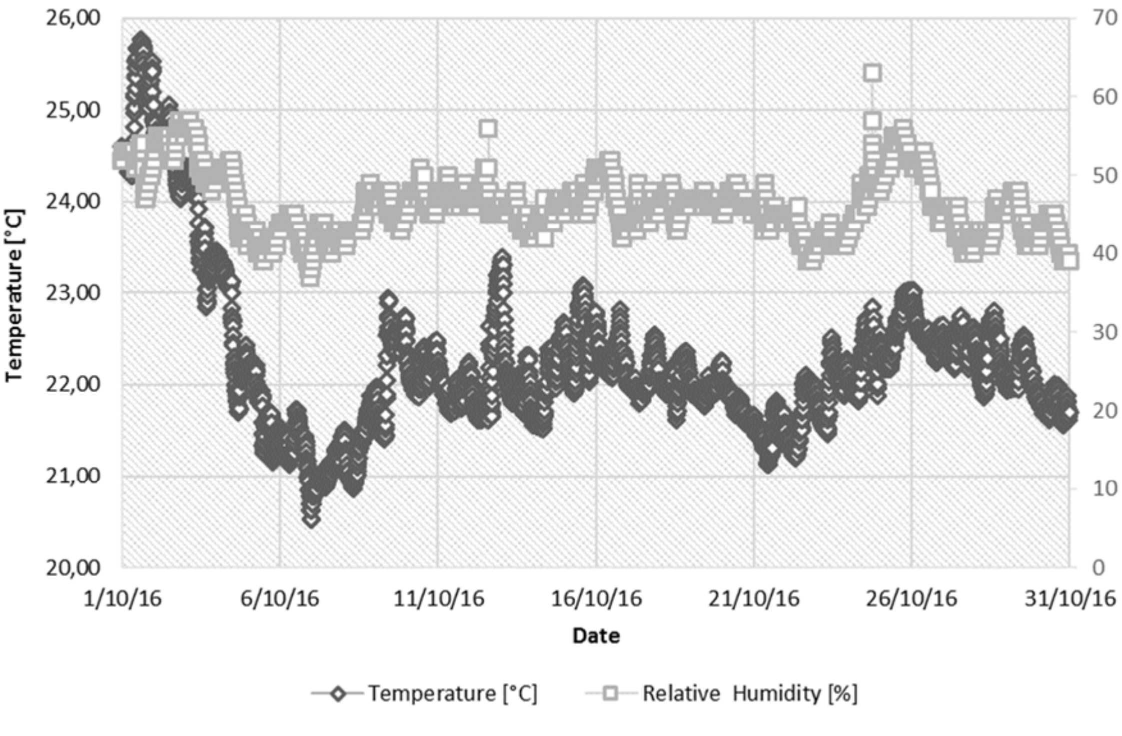

Figure 3. The results of the internal temperature and relative humidity for the non-heating season.

4.2. Results for the heating period

Figure 4 illustrates the results of obtained values of indoor air temperature and relative humidity in apartment of residential buildings represented in 10-minute cycles values during heating period. It is clear indoor environment of prefabricated panel apartments is very dry during the heating period. The mean value of relative humidity during heating period is 35.20% with standard error of ±0.80%. The range between the minimum value (23.00%) and the maximum value (48.00%) is 25%. The variance of obtained valued of relative humidity is 28.25%. There is no humidifier installed. However, aquarium of 120 litres is placed in the room. The effect of evaporation of water from the aquarium is negligible.

The values of 10-minutes indoor are temperatures are shown in figure 4. The mean value of indoor air temperature equals of 22.62 °C. The standard error is ±0.01°C. The temperature of the internal environment is slightly higher (range from 21.08 °C to 25.04°C). The variance of obtained value is 28.25°C.

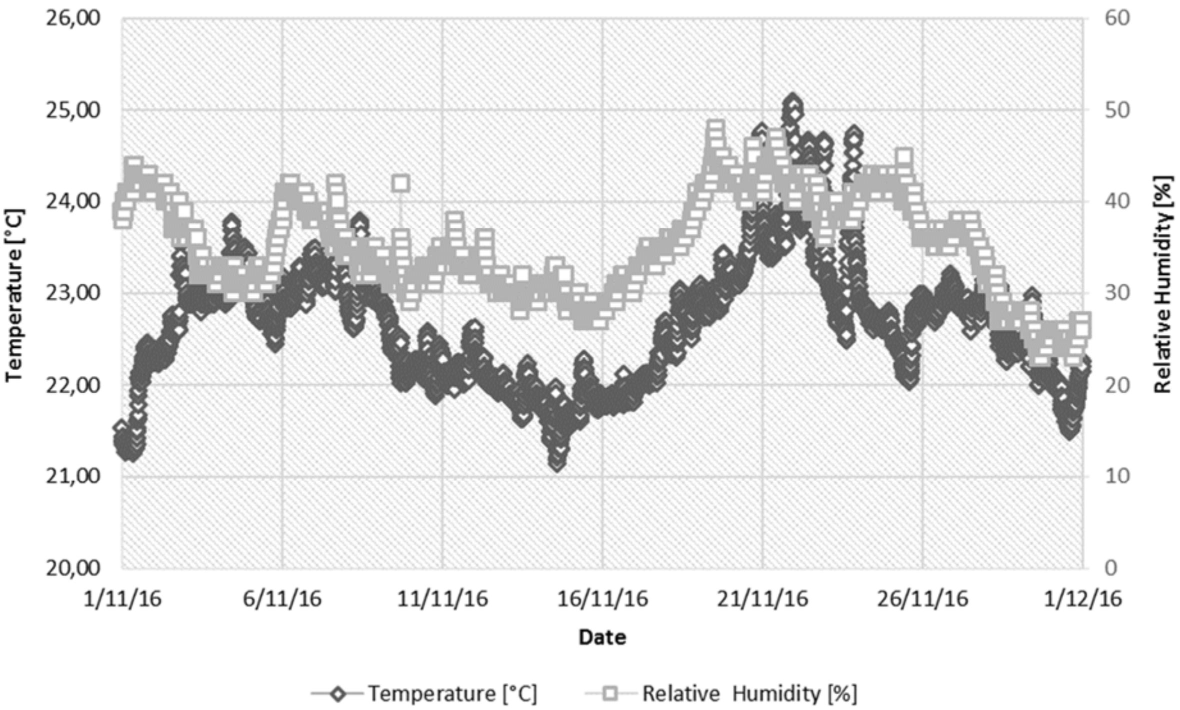

Figure 4. The results of the internal temperature and relative humidity for the heating season.

4.3. Comparison the results of the non-heating and the heating season

The figure 5 shows the obtained values of indoor air temperature and relative humidity according to the period. The different microclimate in the heating and non-heating season is visible at first glance. Optimal internal environment is observed for almost half time of the non-heating season. Part of the measured values form a cluster in areas with higher temperatures and humidity. This area creates favourable conditions for the lives of dust mites.

The dispersion of obtained values during the heating period is considerably lower than in the non-heating period. The measuring points for the heating season form denser cluster of points. Range of temperatures at the start of the heating period is very similar to the non-heating period. Mean temperature is higher by almost 2%. In comparison with the heating season, the decline of relative humidity is obvious. The mean value of relative humidity is decreased by 10%. Part of the values of relative humidity in the heating season has fallen below 30%. Uncomfortable drying of the respiratory mucosa, dry and itchy skin, and the risk of disease characterize this sub-period with RH below 30%.

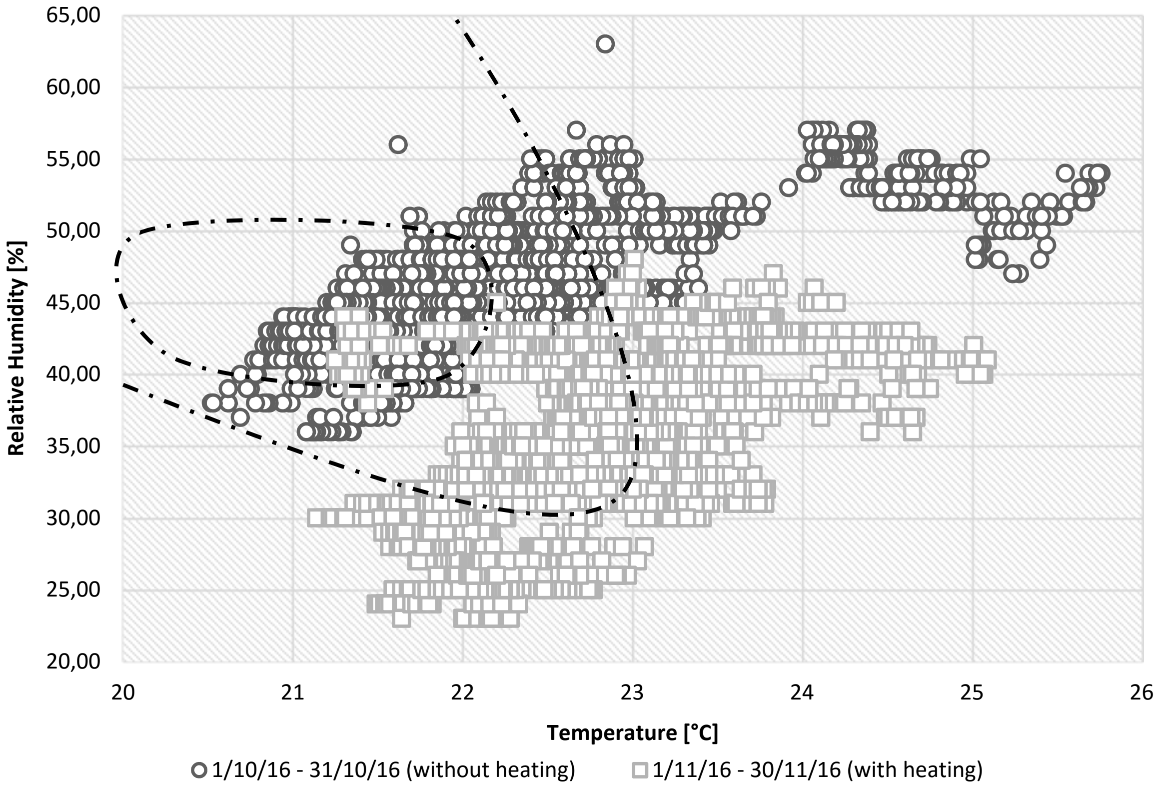

Figure 5. The difference of hygrothermal parameters for non-heating and heating season

5. Conclusions

Indoor air temperature and relative humidity are two essential factor creating the hygrothermal microclimate of indoor environment. The indoor air quality on residential building situated in the Central Europe is affected by seasonal character. The non-heating period generate a relatively suitable microclimate. The wintertime indoor environment (heating period) in the assessed apartment is very dry. Low humidity has a negative effect on comfort of the internal environment. Experimental measurements of hygrothermal microclimate will be supplemented with a subjective assessment of the users of the indoor environment in the next phases of experiment.

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