Indoor Hygrothermal Conditions in Multifamily Dwellings—Measurements and Analysis

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ABSTRACT

In order to design a building envelope that provides for a healthy indoor climate and sustainability, both energy and moisture simulations are needed. Decisions during the building process often are based on results from simulations of energy and moisture. Accurate simulations call for comprehensive input data regarding indoor temperature and indoor moisture supply. Simulations for residential buildings lack the necessary data, a deficit that must be resolved over time in a way that allows both short and long term variations to be described. As a part of an ongoing study, these parameters were measured in 18 apartment buildings containing 325 apartments in total. The parameters were measured at the building level through measurements in the exhaust air of the ventilation system, which provided average values for the apartments. Measurements of the outdoor temperature and relative humidity enabled calculations of moisture supply, which is defined as the difference between indoor vapor content and outdoor vapor content. The parameters were monitored every 30 minutes for one year. The buildings were located in Sweden between latitude N56° and N67°. Examples of results are data on averages, distributions between houses, and variations and spans during the day, during the week, and throughout the year. The presented data can help to improve simulations of indoor climate and energy use in residential buildings, which will make building envelope design decisions more appropriate.

INTRODUCTION

In the building industry, it is necessary to perform calculations regarding energy use and moisture levels in different parts of the construction process to ensure that a building will be sustainable and healthy. The indoor temperature will affect the use of space heating, and the moisture levels will affect deterioration of materials and growth of microorganisms. To accurately predict energy use and moisture levels, input data are needed o simulate energy use and indoor climate and to verify results from simulation programs.

Measurements on indoor temperatures and relative humidity have been made. Kalamees et al. (2006) presented a thorough literature review regarding moisture supply, which is defined as indoor vapor content minus outdoor vapor content. In previous studies, indoor climate was only studied for shorter periods. Holgersson and Norlén (1984) presented measured indoor temperatures in multifamily dwellings. Indoor temperatures were measured in the living rooms between March and May. The average indoor temperature was 21.8°C, and it varied between 20.2°C and 23.8°C.

Indoor temperature and relative humidity were measured in 1800 single-family houses and apartments in multifamily buildings in Sweden (Boverket 2009). Measurements were carried out in 15 minute intervals during two weeks in each house or apartment. The two-week measurement period started between October 2007 and May 2008, depending on location, which resulted in measured data origins from different measurement periods. The average indoor temperature, relative humidity, and moisture supply in multifamily dwellings were 22.3°C, 30%, and 1.22 g/m^3, respectively. Distributions between buildings are presented but not distributions during the measurement periods.

Kalamees et al. (2006) measured indoor humidity loads in 100 bedrooms and 79 living room in 101 single-family

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detached houses during 2002 and 2004. During periods with outdoor temperatures at or below 5°C, the average moisture supply was 1.8 g/m^3; during periods with outdoor temperature over 5°C, the average moisture supply was 0.5 g/m^3. The difference between bedrooms and living rooms was small. Moisture supply figures of up to 4 g/m^3 are given for use in moisture design of dwellings (Nevander and Elmarsson, 1994).

Kalamees et al. (2009) studied the span between the maximum and minimum daily indoor temperature, relative humidity, and vapor content based on hourly measurements during one year in master bedrooms and living rooms in 170 detached houses in Finland. The average amplitudes during summers and winters were 0.9°C and 1.0°C, 6% and 6%, and 1.5 and 1.3 g/m^3, respectively. Standards regarding hygrothermal conditions, such as EN 13788 (2001) and EN 15026 (2007), do not give any information regarding variations during the day and the week.

Elmroth (2002) calls attention to that it is too common that measured energy use exceeds predicted use. Bagge and Johansson (2009) highlighted several projects where the measured use exceeded the predicted by 50% to 100% although energy efficient goals during the planning. Karlsson et al. (2007) studied energy use in passive houses built in Sweden. The measured energy use during operation was 50% higher than the use predicted during the design phase. This was partly due to higher indoor temperature and less efficient heat exchangers than predicted. Karlsson stressed the importance of accurate input data for energy simulations. The building users' behavior is very important in low-energy buildings and also the hardest to model according.

According to the literature, there are large deviations between predicted and measured energy use in residential buildings during operation, and deviations may be suspected for predicted and measured moisture conditions in buildings during operation. Kalamees et al. (2009) studied the dampening effect of hygroscopic materials and concluded that there was a considerable difference between simulated and measured values. Simulations are often executed with conditions that are not common in real buildings, and, for example, the difference in quality of workmanship is hard to take into account in simulations. Page et al. (2008) argued that although simulation models are developed to represent the physics of the building more and more accurately, the model of the inhabitants' behavior is too simplified, which leads to errors in predictions. According to Rode and Grau (2008), whole building hygrothermal simulations show that the amplitudes of indoor humidity can differ significantly, depending on whether the moisture buffering effect of building materials is included.

As buildings become more energy efficient through reduced thermal transmission and reduced ventilation heat loss, building users' energy-related behavior will have a greater effect on the buildings' total energy use. The thermal transmission is reduced by use of highly insulated climate envelopes, which might increase the risk of moisture damage if the constructions are not appropriately designed. The design of moisture-safe constructions are carried out using simulation tools. To ensure correct simulation results, appropriate data are needed on indoor hygrothermal conditions, since differences between indoor and outdoor conditions are the driving forces behind moisture and heat transport.

Conclusively, there seems to be a lack of building user-related data that show both variations during the year and the day, particularly for many parameters that can be correlated, including many apartments. Therefore, Bagge and Johansson (2008a; 2008b) began a study on household electricity use, domestic hot-water use, indoor temperature, indoor relative humidity, moisture supply, moisture production, CO_2 production, and occupancy with readings every 30 minutes for more than a year in 18 multifamily dwellings composed of 325 apartments. This paper presents results for indoor temperature, relative humidity, and moisture supply.

METHODS

Measured and Calculated Parameters and Definitions

By measuring the exhaust air of residential buildings, as opposed to measuring for each individual apartment, a large number of apartments could be included in the study at a reasonable cost. On the other hand, it is not possible to measure distributions between apartments inside a certain residential building or between different rooms in an apartment. The measured parameters related to this paper are temperatures in the central exhaust duct and outdoors, and relative humidity in the central exhaust duct and outdoors. Moisture supply can be calculated using these parameters. Measurements were performed every 30 minutes to make it possible to obtain daily and weekly time distributions as well as daily and weekly spans. Outdoor temperature and outdoor relative humidity were bought from the Swedish Meteorological and Hydrological Institute, which monitors outdoor climate conditions every three hours. All parameters were measured during at least one year to obtain annual time distribution and to evaluate the methods during different outdoor conditions.

Moisture supply, v_{ms}, is defined as the difference between indoor and outdoor vapor content. Vapor content is defined as the mass of water vapor per volume of mixture of water vapor and air. Saturation vapor content, v_{sat}, as a function of air temperature, t, was calculated according to Equation 1, with an error less than 0.07 g/m^3 compared to tabled data presented by Nevander and Elmarsson (1994).

$$v_{sat} = 4.7815706 + 0.34597292 \cdot t + 0.0099365776 \cdot t^2 + 0.00015612096 \cdot t^3 + 1.9830825 \cdot 10^{-6} \cdot t^4 + 1.5773396 \cdot 10^{-8} \cdot t^5 \tag{1}$$

In the analysis, the word "span" is used to describe the difference between a maximum and minimum value during a certain period of time. Daily temperature span means the highest 30 minute temperature reading minus the lowest 30 minute temperature reading during a 24 hour period. Weekly temperature span means the highest minus the lowest daily average temperature during a calendar week, Monday through Sunday.

Studied Cases and Their Location

The buildings studied are presented in Table 1. All the buildings used mechanical exhaust-air ventilation. The measurement periods, the yearly average outdoor temperature, and the number of hours at or below the average outdoor temperature at the different locations are presented in Table 2.

Measuring Equipment and Possible Errors

Temperatures are measured using loggers with a specified error of ±0.35°C. Based on general experience, the specified error for these devices seldom exceeds ±0.2°C. Relative humidity is measured using the same loggers, and relative humidity error is given to 2.5% absolutely. The loggers were calibrated before measurements in order to decrease the number of possible errors.

The lack of measurements for single rooms leads to problems knowing if a measured value is the airflow weighted average value for an entire apartment or only the airflow weighted point value at the exhaust device. On the other hand, measuring in a single room does not give information on the entire apartment. It is believed that the measurements represent the conditions in the apartment. The measured values for indoor temperature and relative humidity include the possible effects of moisture buffering and heat storage of the building and of movables, such as furniture, paintings and books. An important task in this study was to determine the airflow rate that changed air in the buildings. In addition to mechanical ventilation systems, buildings are exposed to leakage due to wind and buoyancy, which also change air in apartments. The actual air change rate could be measured with tracer gas methods, but this would be expensive to do annually and unrealistic if many buildings are to be included. On the other hand, the error caused by neglection of air change due to wind and buoyancy has been minimized by using buildings with mechanical exhaust air only, which leads to a larger under pressure inside the building that reduces exfiltration and, consequently, air change from leakage. Typically, the leakage is decreased by a factor of 5 compared to a building with balanced ventilation (Johansson 2005). If a building has mechanical exhaust and an air tightness of 0.8 L/(s·m^2 surrounding walls) at 50 Pa testing pressure, a constant airflow rate of 1%·0.8 L/(s·m^2) can be assumed in normal conditions (Johansson 2005). If the surrounding area is assumed to be 1.4 m^2 per 1 m^2 floor area, 0.011 L/(s·m^2 floor) is added to the mechanical ventilation. This can be corrected for in the analysis but is small compared to the former Swed-

Table 1. Buildings Studied

Location	Building	Year Erected	Number of Apartments	Number of Stories
Karlstad	1	2005	23	4
	2	2005	22	4
	3	1964	34	9
	4	1964	36	9
	5	1940	24	2
Kiruna	1	1963	9	3
	2	1963	9	3
	3	1963	12	3
	4	1963	10	3
	5	1963	11	3
Malmö	1	1971	24	8
	2	1971	16	8
	3	1971	16	8
	4	1971	16	8
Sundsvall	1	1969	12	3
	2	1969	18	3
	3	1969	18	3
	4	1969	15	3

Table 2. Measurement Periods, Yearly Average Outdoor Temperature, and Number of Hours of Outdoor Temperature at or below the Average at Different Locations

Location	Start Date	End Date	Average Outdoor Temperature, C°	Hours at or below Average Temperature, h
Karlstad	2008-06-12	2009-07-07	5.5	4089
Kiruna	2008-07-05	2009-08-19	–1.7	3749
Malmö	2008-10-10	2009-11-23	8.2	3872
Sundsvall	2008-09-05	2009-09-29	3.6	4336

ish building regulation (Boverket 2002) that requires a ventilation airflow rate of 0.35 L/(s·m^2 floor). In addition to exhaust ventilation in buildings studied, kitchen stove air was transported through the same ducts as the rest of the exhaust air. Exhaust air was in general taken from bathrooms and kitchens, and outdoor air inlets were located in bedrooms and living rooms.

If people inside the buildings open windows, the air change increases dramatically (Nordquist 2002). This could mean that during the summer period the measured values for moisture are only valid close to the exhaust devices.

The measured indoor temperature can include errors if, for example, it is measured in the central exhaust duct, if the ducts are not insulated, or if ducts are located in cold spaces. These things are visible in buildings or on construction drawings. Cold air can also be drawn into the system via leakage in the exhaust duct system, which may result in inaccurate airflow rate measurements. Measured temperatures and relative humidity are not presented where exhaust ducts were partly located outside the climate envelope, for example on unheated attics. Measured temperatures were found to be considerably affected by attic temperature. The temperatures measured in the main exhaust duct were assumed to be the average indoor temperature of the apartments in buildings where exhaust ducts were located inside the climate envelope. In all buildings studied, the central exhaust duct included exhaust air from common spaces, such as staircases and storage rooms, so the measured values are the average values for the whole ventilated volume inside the building.

Analysis

The variations in indoor temperature, relative humidity, and moisture supply during the year, week, and day were analyzed. Variations during the year are presented as monthly averages. The weekly variations were calculated as the difference between a specific day's average measured value and the corresponding weekly average. Variations during the day were calculated as the difference between each 30 minute measured value and the corresponding daily average measured value. Variations during the day were calculated for weekdays and weekends, respectively. Variations are presented as averages of these differences for the whole year and for the seasons—winter, spring, summer, and autumn, respectively. Winter is defined as December through February, spring as March through May, summer as June through August, and autumn as September through November. The variations presented give typical daily and weekly profiles with information on at which time of day and week peaks, increases, and decreases typically occur.

The method for calculating variations during the week and day means that the difference between the highest and the lowest value in the variations presented will be smaller than the average span defined if the maximum or minimum occurred at different times of the day or week, respectively. Even if the resulting variation is smaller than the logger error, the logger error is believed to be random and did not strike at certain times of the day or week.

Daily and weekly spans were calculated to give the magnitude of the variations. Daily spans were calculated as the difference between the highest and lowest values during a day, and weekly amplitudes were calculated as the difference between the highest and lowest daily average value during a week.

RESULTS

The indoor temperature, moisture supply, relative humidity, and corresponding standard deviations are presented for outdoor temperatures less than and higher than the yearly average outdoor temperature, according to Nevander and Elmarsson (1994) in Tables 3 and 4, respectively.

Figures 1 through 3 present the variations during the year, Figures 4 through 7 present the variations during the week, and Figures 9 through 14 present the variations during the day. Tables 5 and 6 present the average span of variations during the week and during the day. Figure 8 presents the duration of the weekly span, and Figure 15 presents the duration of the daily span.

DISCUSSION AND CONCLUSIONS

The average indoor temperature during periods with outdoor temperature less than the yearly average was 22.21°C, which agrees with results from other studies. The average indoor relative humidity was 34% and the average moisture supply was 2.14 g/m^3, which are both higher than reported averages from other studies (see Tables 3 and 4). This might be due to the measurement methods of other studies, which measured in bed rooms and living rooms. In these other studies, moisture generation in bathrooms and kitchens might not be part of the full measured values since residential ventilation is designed for flow paths from bed rooms and living rooms to kitchens and bathrooms. Measuring in the central exhaust air should give a better interpretation of the conditions inside the climate envelope. Boverket's (2009) average is based on averages from a measurement period of two weeks beginning between October and May. If measurement period start times were not evenly distributed between October and May, there could be an over- or underestimation due to variations throughout the year, as presented in Figures 2 and 3, which means Boverket's data is not directly comparable to the results of this study.

Analysis of the variations during the year, week, and day gives information on the typical characteristics of indoor temperature, relative humidity, and moisture supply. Variations during the year and day (see Figures 9, 11 and 13) shared characteristics for all locations, while variations during the week (see Figures 4 through 7) seem to have no common characteristics. It was believed that indoor temperature would be higher during weekends the on weekdays due to an expected higher occupancy level. Variations during the year were considerable, especially for moisture supply and indoor relative humidity, but

Table 3. Average and Standard Deviation of Indoor Temperature, Moisture Supply, and Indoor Relative Humidity for Outdoor Temperatures at or below the Yearly Average Outdoor Temperature

Location	Building	Indoor Temperature, C°		Relative Humidity, %		Moisture Supply, g/m^3	
		Avg	σ	Avg	σ	Avg	σ
Karlstad	1	22.5	0.38	34.5	3.90	3.09	0.69
	2	22.1	0.52	34.3	4.22	2.86	0.62
	3	22.6	0.40	33.3	4.38	2.87	0.61
	4	22.4	0.39	30.7	4.68	2.27	0.59
	5					2.33	0.64
	Average	22.4	0.42	33.2	4.30	2.77	0.63
Kiruna	1					2.08	0.63
	2					1.81	0.62
	3					1.62	0.59
	4					1.31	0.51
	5					1.92	0.56
	Average					1.75	0.58
Malmö	1	22.7	1.10	34.0	5.25	2.25	0.73
	2	21.9	0.91	33.4	5.16	1.80	0.68
	3	21.7	1.00	35.4	5.11	2.03	0.65
	4	22.0	1.24	33.8	5.35	1.89	0.68
	Average	22.1	1.06	34.1	5.22	1.99	0.69
Sundsvall	1					2.40	0.72
	2					1.59	0.63
	3					2.33	0.72
	4					1.92	0.61
	Average					2.06	0.67

the variations for relative humidity are believed due to outdoor climate variations. Monthly mean values for indoor relative humidity (see Figure 2) were highest during the summer months and lowest during the winter months; moisture supply (see Figure 3) was lowest during the summer months and highest during the winter months. The monthly average indoor temperatures (see Figure 1) were higher during the summer months and on a fairly constant level during the rest of the year. The difference in average moisture supply during cold and warm periods of the year (i.e., winter and summer) agreed with results from Kalmees et al. (2006). During the day, the indoor temperature was at minimum around 06:00 and at maximum around 19:00 (see Figures 9 and 10). The increase in temperature during the day may be due to solar heat gains, and the maximum value in the evening might be due to increased internal heat gains from household electricity that peaks at the same

Table 4. Average and Standard Deviation of Indoor Temperature, Moisture Supply, and Indoor Relative Humidity for Outdoor Temperatures over the Yearly Average Outdoor Temperature

Location	Building	Indoor Temperature, C°		Relative Humidity, %		Moisture Supply, g/m^3	
		Avg	σ	Avg	σ	Avg	σ
Karlstad	1	24.4	1.70	44.6	6.11	2.15	1.24
	2	24.1	1.50	44.7	6.37	1.98	0.98
	3	23.7	1.32	45.4	7.08	1.85	1.00
	4	23.2	1.24	45.00	7.85	1.53	0.97
	5					1.55	1.12
	Average	23.9	1.44	44.9	6.85	1.88	1.05
Kiruna	1					0.82	0.83
	2					0.67	0.81
	3					0.39	0.81
	4					0.32	0.72
	5					0.86	0.74
	Average					0.61	0.78
Malmö	1	23.7	1.43	48.5	4.88	1.40	0.92
	2	23.5	1.58	47.5	4.74	1.07	0.93
	3	23.2	1.49	49.4	4.73	1.22	0.86
	4	23.1	1.43	49.1	5.45	1.17	0.88
	Average	23.4	1.48	48.6	4.95	1.22	0.90
Sundsvall	1					1.36	0.92
	2					0.73	0.94
	3					1.46	0.96
	4					1.22	0.91
	Average					1.19	0.93

time as temperature (Bagge 2008). During the night there are usually less internal heat gains from household electricity and no solar heat gains, which might explain the minimum in the morning. As people begin their morning practice, internal heat gains increase. Indoor relative humidity typically decreased during the night, with a minimum at around 06:00, after which it increased and remained relatively constant during the day (see Figures 11 and 12). During summer, the indoor relative humidity was constant during the night and increased during the morning to a maximum at around 10:00, after which it decreased to a minimum at 18:00. During summer, window airing is suspected of being used to control indoor temperature, which affected the measured relative humidity and moisture supply as discussed in the "Methods" section of this paper. The variation in moisture supply during the day had the same general characteristics as the indoor relative humidity, except during summer where the moisture supply decreased during the night and had a negative spike around 06:00, after which it

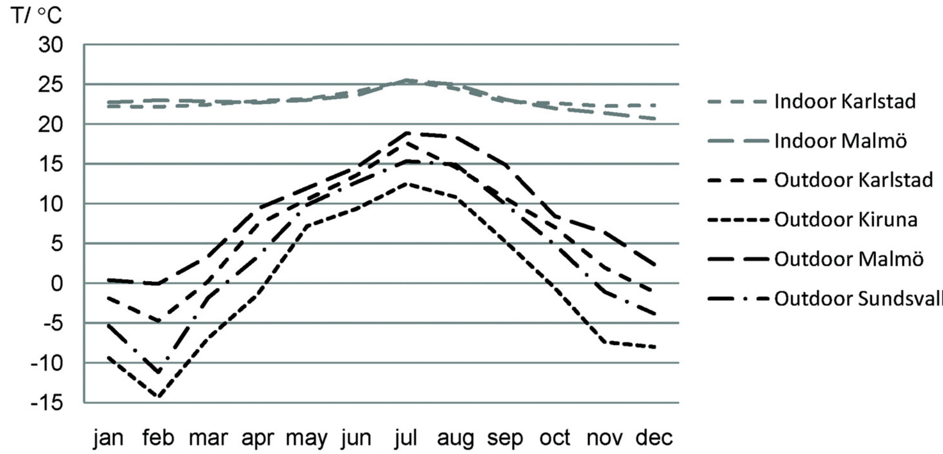

Figure 1 *Monthly average indoor and outdoor temperatures, T, at the different locations during the measured period. Indoor temperatures are average values of all buildings at a specific location.Depending on the start date of the measurement period, the presented monthly averages are from different years.*

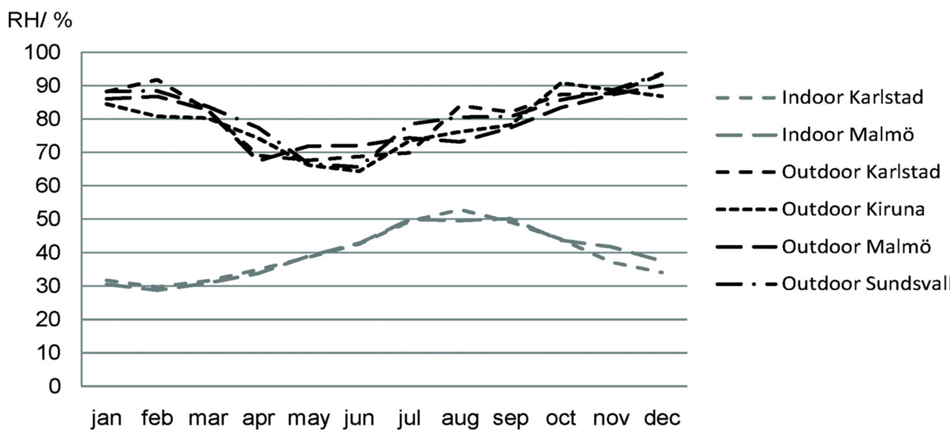

Figure 2 *Monthly average relative humidity, RH, indoors and outdoors at the different locations during the measurement period. Indoors are average values of all buildings at a specific location. Depending on the start date of the measurement period, the presented monthly averages are from different years.*

increased and remained at a constant level during the afternoon, decreased during the evening, and increased around midnight (see Figures 13 and 14). Generally, for all studied parameters, the increase during mornings begins later during weekends compared to weekdays, which most certainly is due to occupants waking later in the morning on weekends. Computer simulation tools for energy use and hygrothermal conditions in buildings often give the user the option to define different indoor conditions during weekdays and weekends, respectively. Results from this study show there were not greater differences in average indoor temperature, indoor relative humidity, and moisture supply between weekdays and weekends as compared to differences for random days.

Weekly and daily variations were small compared to the possible equipment errors. It is believed that the equipment errors are random, but if there were a systematic error, it may have influenced the average variations. It is difficult to acquire information on the types and causes of equipment errors, particularly for humidity measurements. The result on spans of daily and weekly variations shows that an arbitrary day's or week's variation is far higher than the equipment error, which indicates reasons other than equipment errors for the resulting variations (see Figures 8 and 15 and Tables 5 and 6).

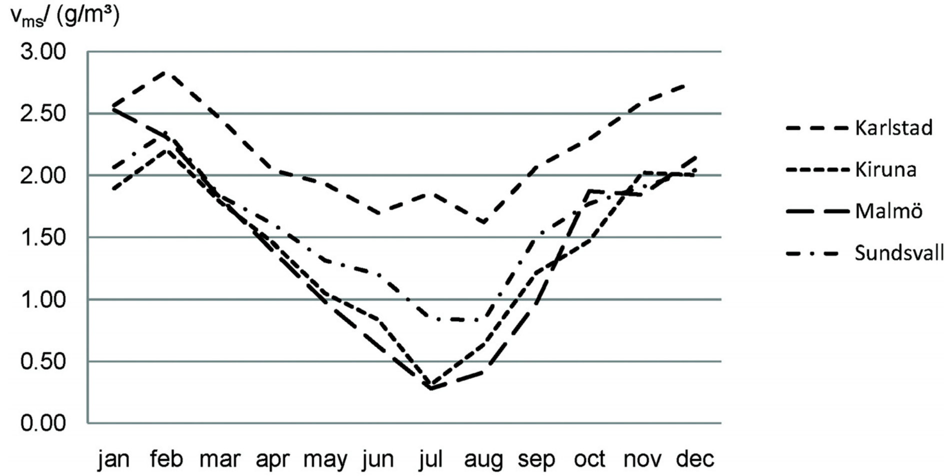

Figure 3 *Monthly average moisture supply indoors and outdoors at the different locations during the measurement period. Indoors are average values of all buildings at a specific location. Depending on the start date of the measurement period, the presented monthly averages are from different years.*

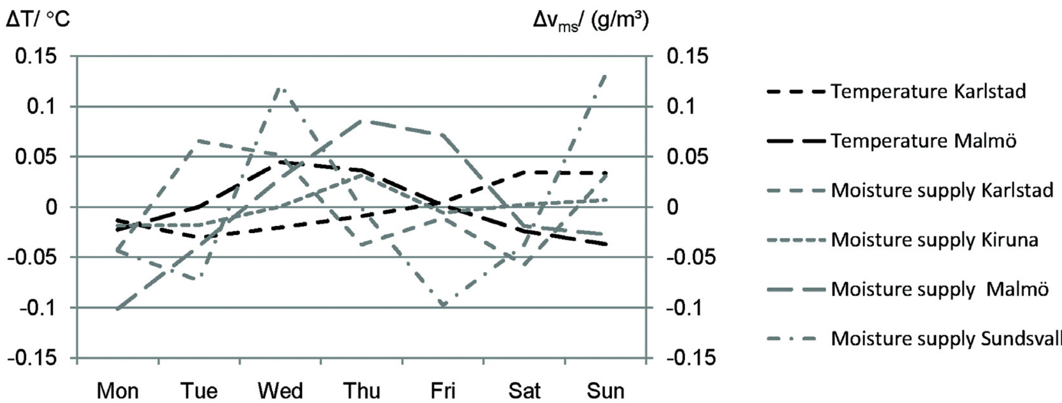

Figure 4 *The variations in indoor temperature and moisture supply during the week. ΔT and Δv_{ms} are the average of (daily average minus weekly average). The presented values are average values of all buildings at a specific location.*

The average daily span—the average difference between the highest and the lowest measured value during a day—of indoor temperature, relative humidity, and moisture supply was 0.58°C, 5.9%, and 1.91 g/m^3. The average weekly span—the average difference between the highest and the lowest daily average during a week—was 0.66°C, 7.1%, and 1.32 g/m^3. The magnitude of both daily and weekly spans indicates measurements need to be performed during longer periods of time if average values are to be obtained. Since the values presented are average values of many apartments, the spans within a single apartment or a single room can be expected to be higher.

Variations during the year and during the day were systematic for all studied parameters and equal for all studied locations, and the span of all studied parameters were of considerable magnitude. If any of the studied parameters is to be measured as an instantaneous value, the effect from the variations during the year, week, and day should be taken into account. If a material located inside the climate envelope is to be studied with regard to moisture, the variations and spans presented should be considered, since they may cause the material to be humidified or dehumidified during different times and, hence, cause hysteresis in the sorption.

ACKNOWLEDGMENTS

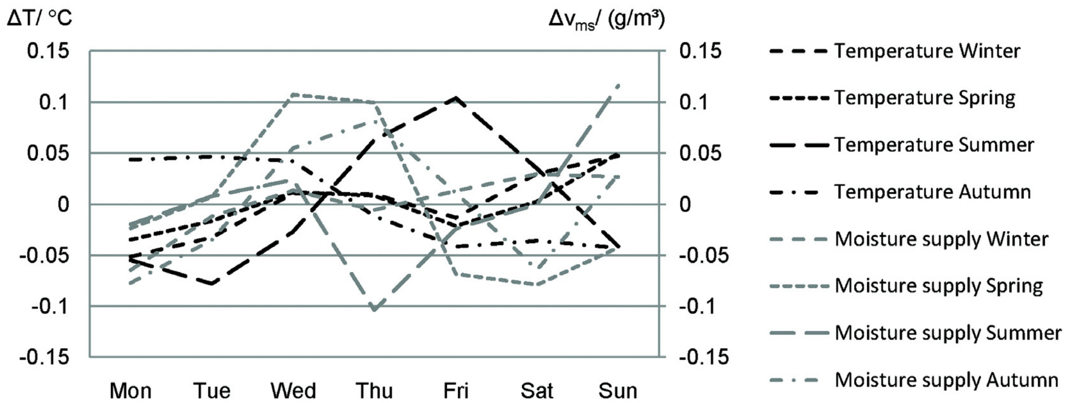

Figure 5 *The variations in indoor temperature and moisture supply during the week for different seasons. ΔT and Δv_{ms} are the average of (daily average minus weekly average). The presented values are average values of all buildings of all locations.*

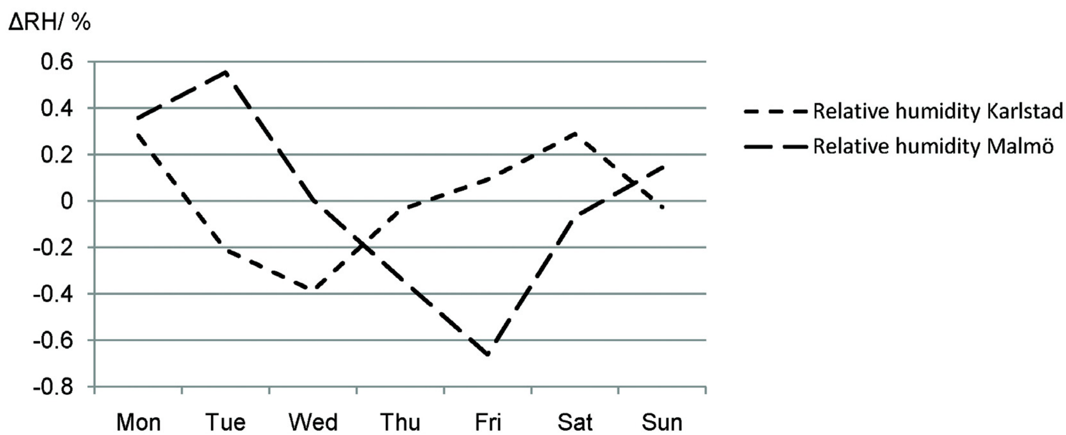

Figure 6 *The variations in relative humidity during the week. ΔRH is the average of (daily average RH minus weekly average RH). The presented values are average values of all buildings at a specific location.*

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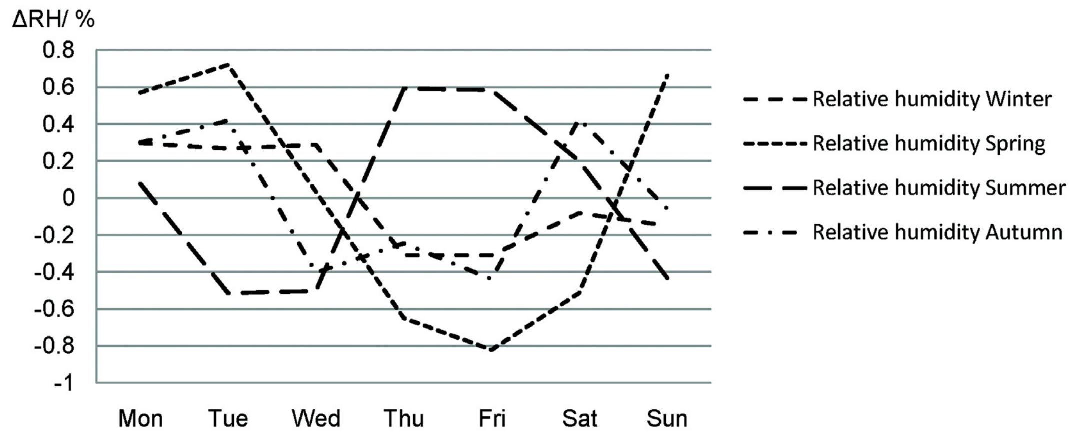

Figure 7 *The variations in indoor relative humidity during the week for different seasons. ΔRH is the average of (daily average RH minus weekly average RH). The presented values are average values of all buildings of all locations.*

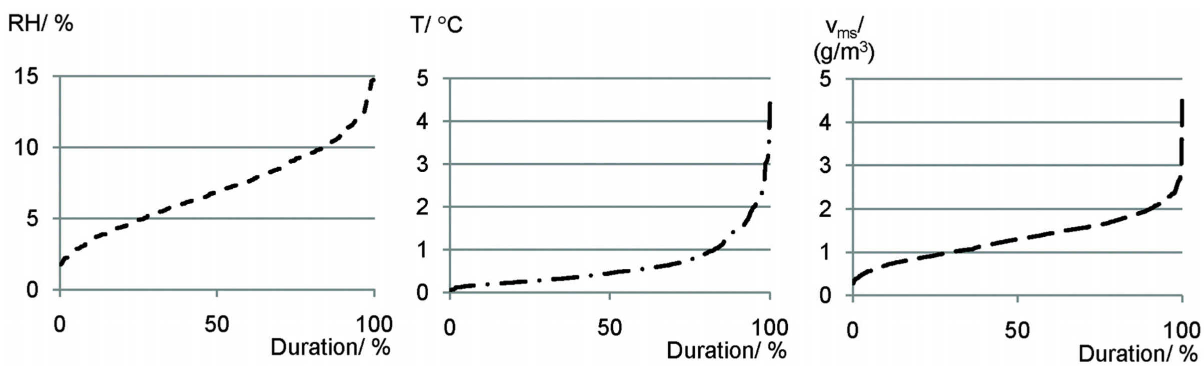

Figure 8 *The duration of the weekly span of temperature, T_{span}; relative humidity, RH_{span}; and moisture supply, v_{ms_span}, respectively. The presented values are average values of all locations.*

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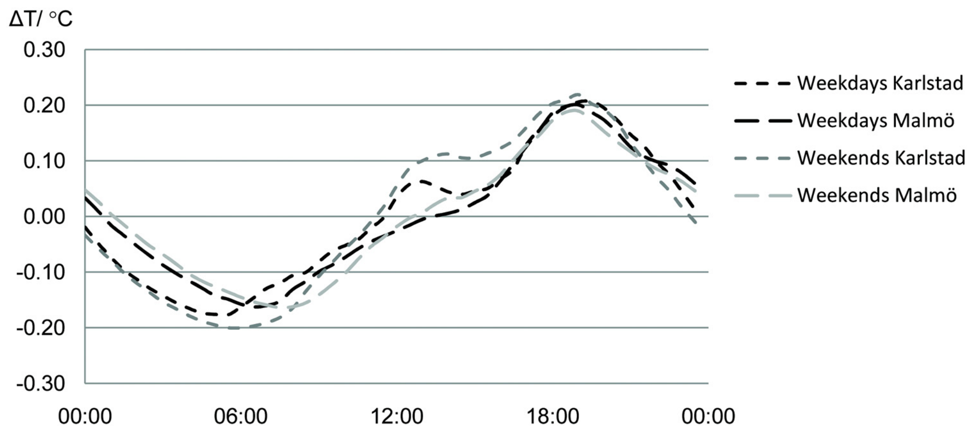

Figure 9 *Variations in indoor temperature during the day, presented for weekdays and weekends respectively. ΔT is the average of (indoor temperature minus daily average indoor temperature). The presented values are average values of all buildings at a specific location.*

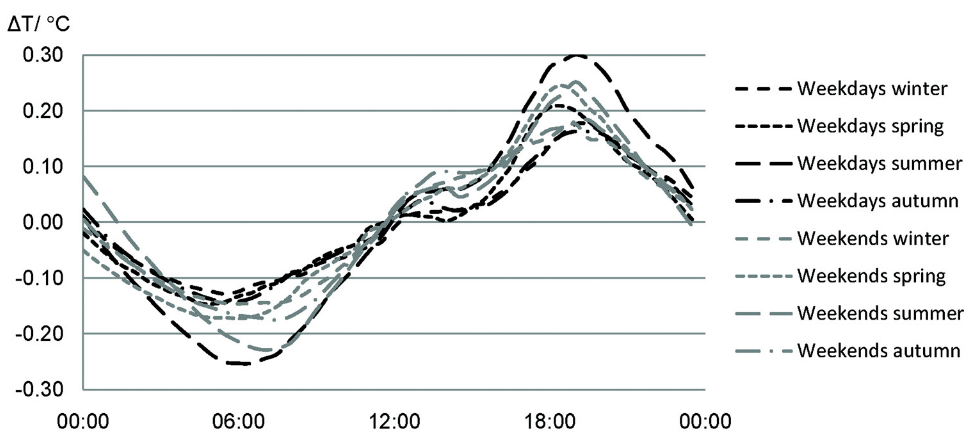

Figure 10 *Variations in indoor temperature during the day for different seasons, presented for weekdays and weekends, respectively. ΔT is the average of (indoor temperature minus daily average indoor temperature). The presented values are average values of all locations.*

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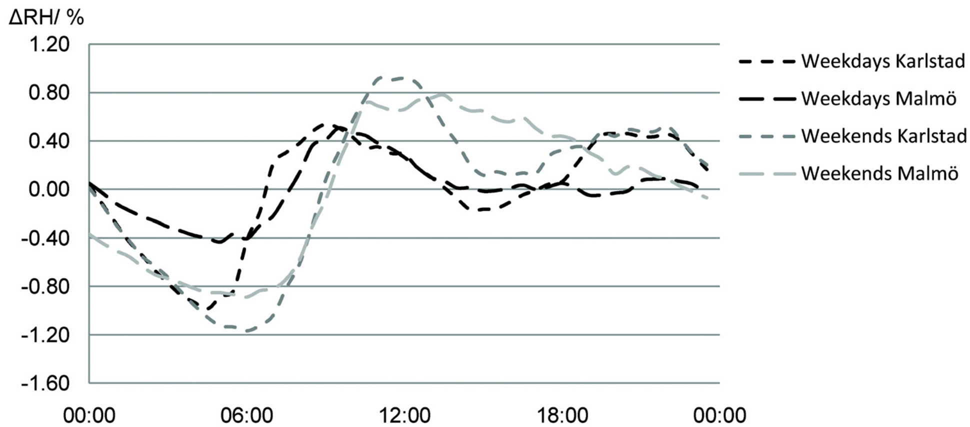

Figure 11 *Variations in relative humidity during the day, presented for weekdays and weekends, respectively. ΔRH is the average of (RH minus daily average RH). The presented values are average values of all buildings at a specific location.*

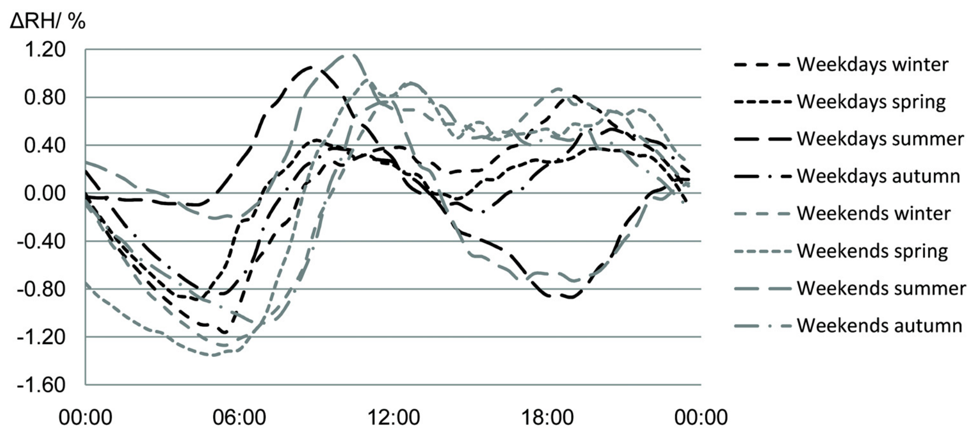

Figure 12 *Variations in relative humidity during the day for different seasons, presented for weekdays and weekends, respectively. ΔRH is the average of (RH minus daily average RH). The presented values are average values of all locations.*

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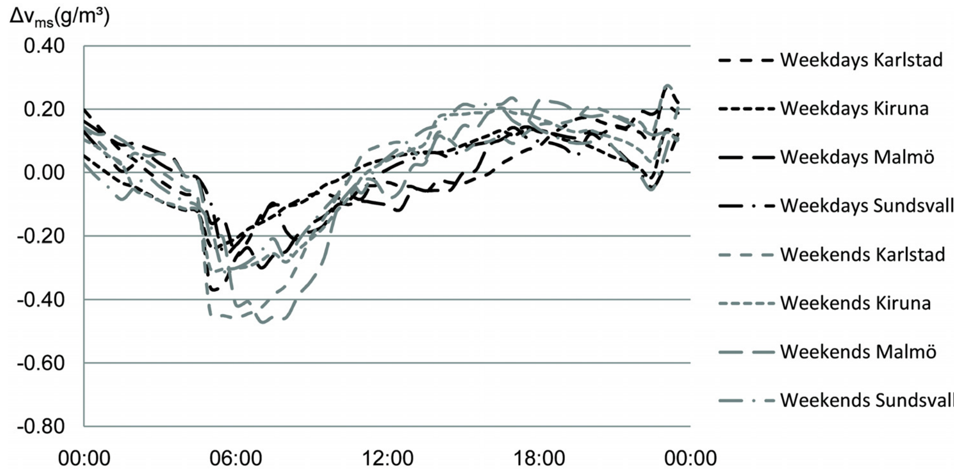

Figure 13 *Variations in moisture supply during the day, presented for weekdays and weekends, respectively. Δv_{ms} is the average of (v_{ms} minus daily average v_{ms}). The presented values are average values of all buildings at a specific location.*

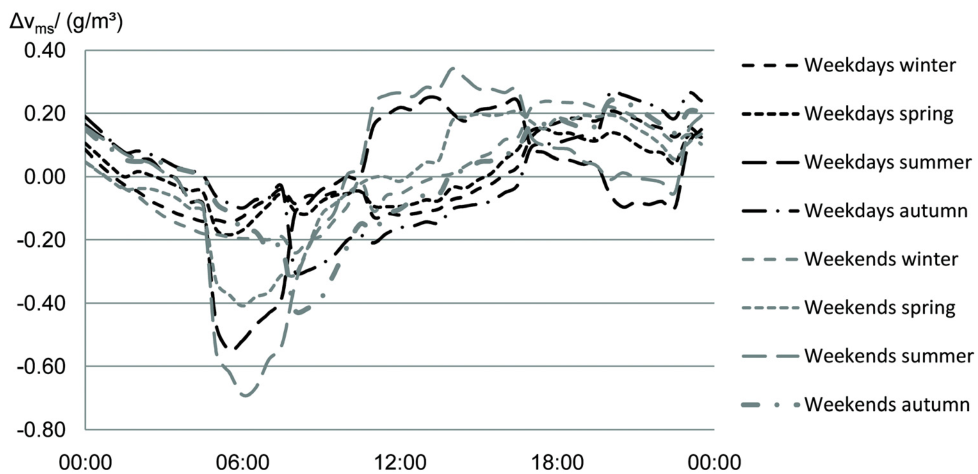

Figure 14 *Variations in moisture supply during the day for different seasons, presented for weekdays and weekends, respectively. Δv_{ms} is the average of (v_{ms} minus daily average v_{ms}). The presented values are average values of all locations.*

Table 5. Average Span and Standard Deviation During the Week for Whole Year and Seasons, Respectively

Period	Indoor Temperature, C°		Relative Humidity, %		Moisture Supply, g/m^3	
	Average	σ	Average		Average	σ
Year	0.66	0.62	7.1	2.9	1.32	0.51
Spring	0.49	0.40	5.0	2.0	1.23	0.48
Summer	0.51	0.33	6.3	2.3	1.15	0.43
Autumn	1.25	0.94	9.0	2.8	1.56	0.55
Winter	0.48	0.31	7.7	2.5	1.29	0.49

Table 6. Average Span and Standard Deviation During the Day for Whole Year and Seasons, Respectively

Period	Indoor Temperature, C°		Relative Humidity, %		Moisture Supply, g/m^3	
	Average	σ	Average		Average	σ
Year	0.58	0.30	6.9	2.6	1.91	0.91
Winter	0.50	0.20	4.9	1.7	1.35	0.57
Spring	0.58	0.28	5.6	2.0	1.74	0.77
Summer	0.76	0.39	7.2	3.5	2.47	0.99
Autumn	0.51	0.23	5.6	2.2	1.95	0.82

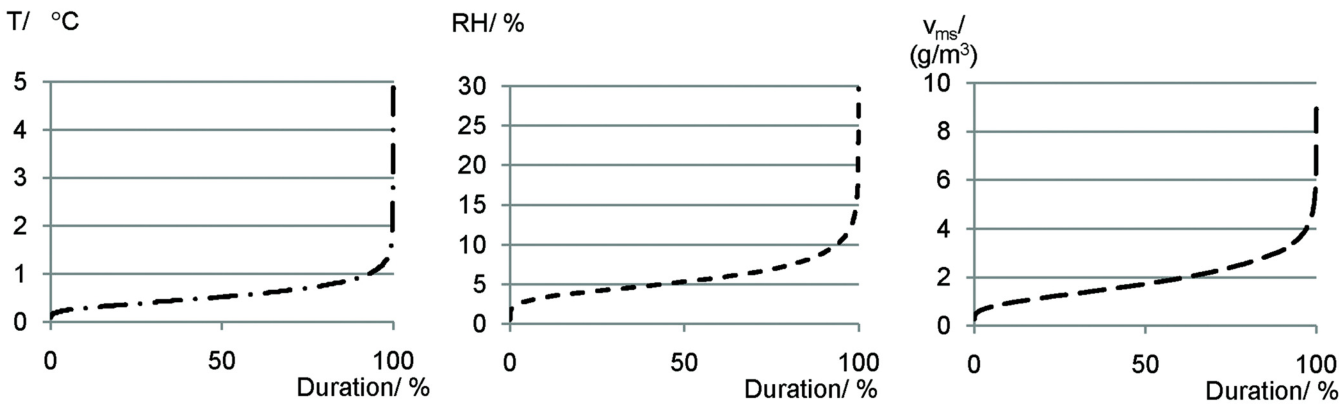

Figure 15 *The duration of the daily span of temperature, T_{span}, relative humidity, RH_{span}, and moisture supply, v_{ms_span}, respectively. The presented values are average values of all locations.*