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Published in:
Energy Procedia

DOI (link to publication from Publisher):
10.1016/j.egypro.2017.09.661

Publication date:
2017

Document Version
Publisher's PDF, also known as Version of record

Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 132 (2017) 141–146

Energy Procedia

www.elsevier.com/locate/procedia

11th Nordic Symposium on Building Physics, NSB2017, 11-14 June 2017, Trondheim, Norway

Moisture supply in Danish single-family houses – the influence of occupant behavior and type of room

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Abstract

According to ISO 13788, the internal moisture supply in dwellings can be described by humidity classes defined by outdoor temperature, occupancy and ventilation. Hygrothermal measurements in indoor air in 500 Danish single-family houses were made to investigate if this corresponds with reality. The study focuses on the dependency of number and age of occupants, occupants' time spent in the house, square meters living space, ventilation habits and type of room. Moisture supply depends on the type of room; bathroom, basement and living room have the highest values. None of the other parameters seems to have a significant effect.

Peer-review under responsibility of the organizing committee of the 11th Nordic Symposium on Building Physics.

Keywords: Dwellings, humidity class, moisture supply, occupancy, type of room, social status, ventilation

1. Introduction

Internal humidity load in buildings located in maritime climate (e.g. Western Europe) can be described by humidity classes according to [1]. These are based on interrelated values of *internal moisture excess* (named *moisture supply* in this paper) and outdoor temperature, depending on the use of buildings including occupancy and ventilation, not considering building style and use of materials. Most Danish single-family houses would be considered to belong to humidity class 2. The question is whether occupant behavior is more important for the moisture supply in a house than the building style.

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1876-6102
Peer-review under responsibility of the organizing committee of the 11th Nordic Symposium on Building Physics
10.1016/j.egypro.2017.09.661

It has been discussed to let an inspection documented in a Home Condition Report (HCR), requested by the owner at sale and made by an building expert, include a snapshot of the moisture conditions to indicate whether a specific house has an increased level of moisture compared to what is “acceptable” [2]. The HCR should lay out the condition of the house compared to what can be expected from a house of similar type and age with a typical/normal level of maintenance. The building inspection is visual with the option of using simple hand-held instruments, if relevant, but with no destructive measures allowed.

If occupant behavior is the most decisive, measuring moisture as a part of building inspection when a house is going to be sold is not very informative; it would only reveal the past not the future. This paper focuses on the effect of occupant behavior on moisture supply. The effect of building style is discussed in another paper presented at the conference [3]. Further details of the study are described in [4].

2. Research method

As no recent systematic measurements of moisture in Danish houses exist, it is not known how much the moisture supply varies houses in-between or how much it changes within a house. Neither is it known whether there are geographical differences or differences between different types of houses. It was estimated that a sample of 500 houses would be sufficient to represent Danish single-family houses. Based on changes in building style and use of building materials seven types of houses were selected, as described in [3].

To evaluate whether geography had any influence, houses were selected from 21 municipalities, representing about 20 % of the Danish population. In total they showed to have a representative amount of occupants’ owned houses and a socio-economic index as for Denmark as a whole. However most of the houses visited were owner occupied. The Danish Building and Housing Register (BHR) was used to divide the houses in building types, from these lists 15-25 houses were randomly selected in each municipality. Each house was visited once for on-site inspection and for placing sensors for logging of temperature and relative humidity for a 14-day period. To ensure that the time of year would not disturb the result, different municipalities were visited at different time of year.

Each visit started with interviewing the occupants on their experience of indoor moisture conditions, and about their cooking, washing and ventilation habits. Also the number and age of occupants, occupants’ time spent in the house (weekdays and weekends), square meter living space and their social status (education and type of work) was part of the interview. Data on construction types, building materials, ventilation system etc. was registered, although it was supposed to be available in the BHR, which unfortunately often not is updated. Data on living conditions, number of occupants, etc. will not be part of a normal house inspection at sale, as the future occupants’ number and habits are not known. However, it has been included in this study to evaluate the effect of occupant behavior on moisture conditions, in case there are differences that cannot be explained by building style.

3. Results

The average indoor temperature for all rooms not including basements was 22.6 °C, highest in kitchens and bathrooms and lowest in bedrooms, as seen in Table 1.

Table 1. Indoor temperature and relative humidity for different types of room. Measurements are primarily made in bathrooms, kitchens and bedrooms. ‘Room, various’ covers children’s room, home office etc. *: Except basement

Indoor temperature (No. of rooms)	All rooms *	Bathroom (426)	Kitchen (365)	Scullery (73)	Living room (241)	Room, various (79)	Bedroom (453)	Basement (32)
Average	22.6	23.0	23.0	22.3	22.8	22.5	21.8	20.6
Std deviation	2.5	2.3	2.1	3.7	2.4	1.9	2.7	3.1
Relative humidity								
Average	53.0	54.0	51.5	52.6	51.7	53.0	54.0	63.9
Std deviation	8.1	8.5	7.4	10.0	8.9	7.9	6.9	12.4

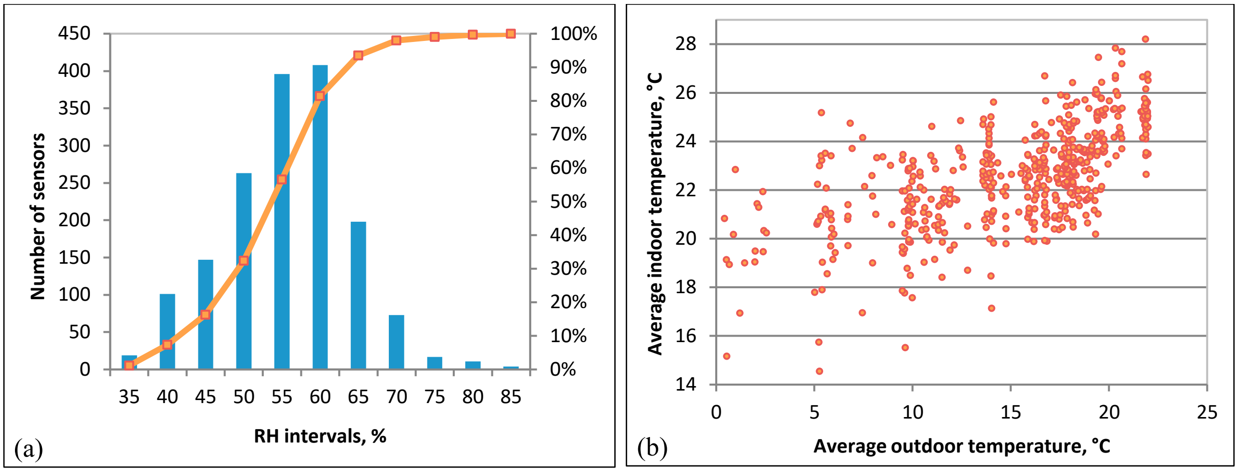

Figure 1. (a) Distribution of relative humidity (RH) based on single sensors located in different rooms. Figures below columns refer to the upper limit of an interval, e.g. 35 represents the interval 30-35. (b) Corresponding values of outdoor and indoor temperatures, average values per house.

The average relative humidity in rooms not including basements was 53 %, with the lowest values in kitchen and living room and the highest in bathroom and bedroom. In the majority of rooms, no matter the type, the average relative humidity was between 35 % and 65 % RH, cf. Figure 1a; although in some cases relative humidity above 80 % RH was measured in bathroom, scullery or basement as an average for a 14 day period. As different houses were visited at different times of year it was possible to see if indoor and outdoor temperature related. As expected the indoor temperature increases with increasing outdoor temperature (Figure 1b).

In total 508 houses were included, primarily single-family houses. In 18 % of the houses the occupants experienced their house as being moist, with the basement as the most often mentioned room (5 %). In 25 % of the houses they reported moisture damage, primarily in bedroom (8 %), basement (5 %) or bathroom (5 %).

4. Discussion

4.1. Social status and age of occupants

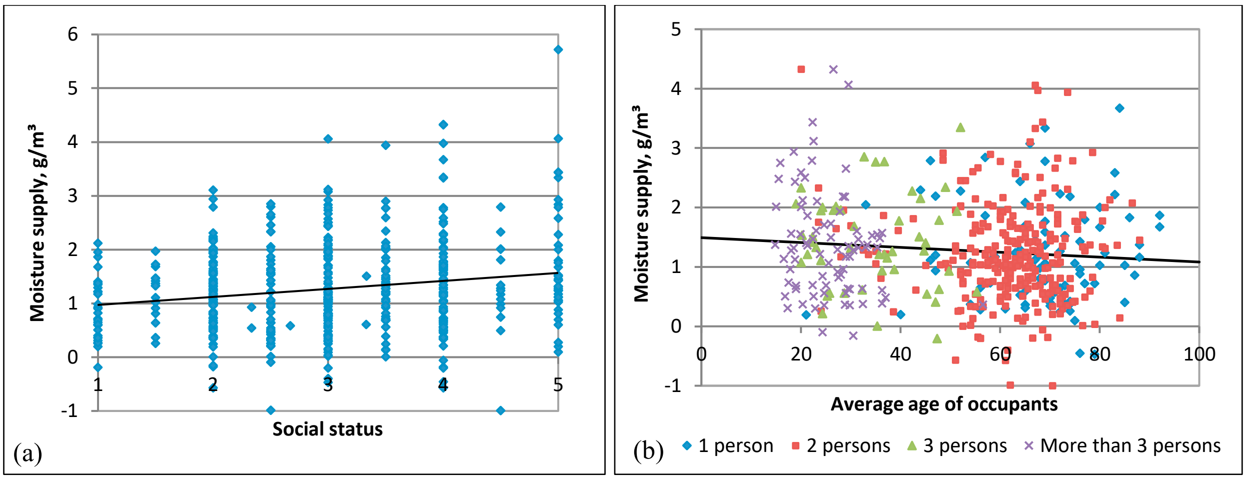

Figure 2. Moisture supply compared with (a) average social status (education and type of work) and (b) average age and number of occupants. 1 is a high social status, 5 is the lowest. Age is expressed as average age of all occupants in a house. (b): One house with a 5.7 g/m^3 moisture supply and 2 persons with an average age of 77 is not shown.

Figure 2 show moisture supply compared with the occupants' social status (a), age and number (b). Age is expressed as average age of all occupants in a house. As expected, the more occupants per house the lower the average age, but moisture supply does not seem to be dependent of social status or average age of occupants. Figure 2a indicates that the moisture supply increases somewhat when the social status decreases (class 5 is the lowest class) and Figure 2b indicates that it decrease a little bit with increasing age. None of these observations are surprising, but in both cases the correlation is weak, although a bit higher for social status (coefficient of correlation about 0.18) than for age (0.1). In the case of age the spread is quite high independent of the number of occupants.

4.2. Occupant density and ventilation habits

Figure 3 show moisture supply compared with occupant density, expressed as square meter living space per occupant (a) and hours per day where the house is occupied (b), taking into consideration the number of occupants. Figure 3a indicates that the moisture supply decreases somewhat when the occupant density decreases (more square meters per occupant), but the spread is quite high independent of the number of occupants. Further, as expected, it can be seen that the fewer the occupants per house the more living space they have. Figure 3b indicates that the moisture supply increases a bit when the total number of hours where the house is occupied increases.

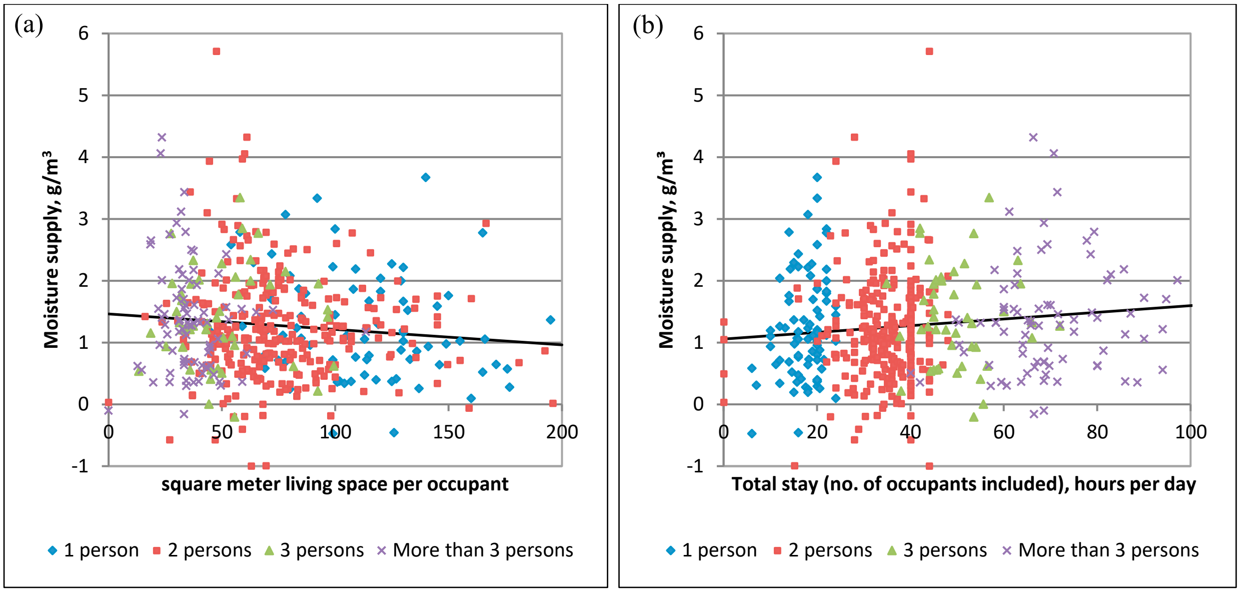

Figure 3. Moisture supply (g/m^3) compared with occupant density, (a) square meter living space per occupant and (b) total number of hours where the house is occupied, including number of occupants. (a): 8 houses each occupied by one person having more than 200 m^2 are not shown (moisture supply between 0 and 2 g/m^3). (b): 2 houses each with a total stay of more than 100 hours are not shown (moisture supply between 1 and 3 g/m^3).

In both cases the correlation between moisture supply and occupant density is very weak (coefficient of correlation about 0.1), showing that the moisture supply is not very much dependent on the occupant density. This is also the case if using the average number of hours per day where the houses is occupied, not taking into consideration the number of occupants.

According to Table 2 almost 90 % of the occupants ventilate the house by opening windows at least once a day. A t-test on the average moisture supply depending on how often occupants open the windows, showed that on a 5 % level there was no significant difference in moisture supply in the four categories. Surprisingly, the lowest moisture supply was measured in houses that were ventilated less frequently than weekly. Nearly half of these houses had a mechanical ventilation system, which might explain why the occupants did not open the windows.

A similar t-test involving occupants' habits regarding indoor drying of clothes (daily, weekly, less frequently or never) could not explain differences in moisture supply either.

Table 2. Moisture supply to indoor air depending on ventilation habits reported by the occupants.

Frequency of ventilation	Multiple per day	Daily	Weekly	Less frequently
Average moisture supply, g/m³	1,26	1,27	1,43	1,07
Standard deviation	0,89	0,83	0,82	0,76
Number of houses (some did not answer)	220	219	36	18

4.3. Type of room

The occupants did primarily experience moisture problems in basement, bathroom or bedroom. This corresponds with the measurements of relative humidity (Table 1), although apart from the basement the difference in relative humidity between types of rooms is very small. Bathrooms have about 33 % higher average moisture supply (g/m^3) than other rooms (Figure 4a). Further, t-tests on a 5 % level show that moisture supply in the various rooms is significantly different, only kitchen and scullery are not. By performing the t-test on the measured relative humidity instead, the picture is different; only few rooms differ from each other. This underlines that information about the relative humidity is not sufficient to assess indoor moisture conditions; also the temperature is needed.

For the 508 houses studied as a whole the correlation between moisture supply and outdoor temperature is not very good (coefficient of correlation 0.5) [3]. By comparing moisture supply per room on a monthly basis with the outdoor temperature the correlation is much better (-0.9), represented by Figure 4b. As expected the moisture supply is lower during summer, probably caused by more frequent opening of windows, although questions on ventilation habits were on a general level, not referring to habits in different seasons. Therefore data on time of year is relevant when assessing whether measurements of moisture conditions indicates a normal level or not.

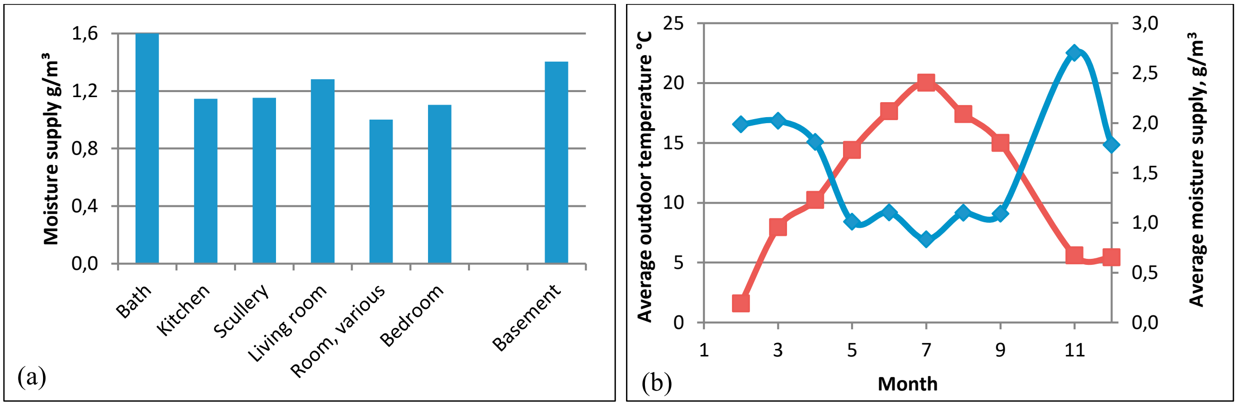

Figure 4. (a) Average moisture supply (g/m^3) in different types of room. 'Room, various' covers children's room, home office etc. (b) Outdoor temperature (red) and moisture supply (blue), monthly based average values. Average moisture supply for a specific month is based on average moisture supply for each room in each house included in measurements in a specific month.

4.4. Occupant behavior – important for the moisture supply?

If the occupant – except from visible damage caused by moisture – has the main influence, there is no need systematically to let moisture measurements be part of a house inspection in connection with a sale, as this requires reliable information on occupants' moisture related behavior. A visual inspection including measurements at visible moist areas will be sufficient. Only in the case of a housing association performing measurements in several uniform dwellings showing high values in most cases, an effect from the building itself should be taken into consideration.

Another part of the study shows that the spread on moisture supply in single-family houses is quite high; in 32 % of the cases the average moisture supply was higher than the upper limit of humidity class 2 (HC 2) and in 40 % it was lower than the lower limit [3]. Only 28 % were within the limit of HC 2. However, the large spread cannot be explained by occupant behavior expressed as social status, age, occupant density, ventilation habits or indoor drying of clothes. As the study is based on mainly owner occupied single-family houses the results are not necessarily representative for single-family houses in general or for dwellings.

Measurement of indoor temperature is important when evaluating indoor climate and risk of mold growth, as indoor temperature is very often higher than 20 °C, normally assumed when simulating moisture conditions; in this case the average indoor temperature was 22.6 °C.

Further the study shows that it is difficult to choose in which room temperature and relative humidity sensors should be placed, as the moisture supply are significantly different in all type of room except kitchen and scullery. Measurements in bathroom and basement (if any) are always important, as the risk of a high moisture load is expected to be higher than in other rooms.

Habits regarding ventilation and indoor drying of clothes are self-reported and may therefore be biased, but as the study was not made to monitor the occupants or to document whether the occupants behave reasonably in regard to moisture, there is no incentive for the occupants not to tell the truth. They have agreed on participating in a research project; no one outside the project, including the occupants, will receive results from single houses.

5. Conclusion

Differences in moisture supply in Danish single-family owner occupied houses cannot be explained by one single parameter relating to occupant behavior: Social status, age, occupant density, ventilation habits or indoor drying of clothes. However, the study showed that:

- Moisture supply tends to be smaller in the summer, which may be explained by occupants' ventilation habits, although occupants were not asked whether they opened windows more often during summer.
- Moisture supply depends on the type of room; bathroom, basement and living room have the highest values.
- Measurement of indoor temperature is important when evaluating indoor climate and risk of mold growth, as it is very often higher than 20 °C, normally assumed when simulating moisture conditions. Time of year measuring indoor relative humidity and temperature is also important when assessing moisture conditions and risk of mold growth.

Acknowledgements

This study was made possible by a grant from the former Danish Ministry of Housing, Urban and Rural Affairs.

References

[1] European Committee for Standardization. Hygrothermal performance of building components and building elements – Internal surface temperature to avoid critical surface humidity and interstitial condensation – Calculation methods (ISO 13788:2012).

[2] Ministry of Justice. White paper on House Inspection System (author's translation from Danish) (White Paper No. 1520). Copenhagen; 2010.

[3] de Place Hansen EJ and Møller EB. Moisture supply in Danish single-family houses – the influence of building style. Accepted for 11th Nordic Symposium of Building Physics (NSB 2017), Trondheim; 2017.

[4] Møller EB. Moisture in Danish houses (author's translation from Danish) (SBi 2017:xx). Copenhagen: Danish Building Research Institute, Aalborg University; 2017. (in press).