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Measurements of microclimates in beds in relation to the climatic requirements of house dust mites

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KEYWORDS: *measurements, temperature, relative humidity (RH), mattress, bedding, bed, house dust mites (HDM), climatic conditions, material properties.*

SUMMARY:

House dust mites are animals of a size less than 0.5 mm that can live in beds, carpets and furniture feeding on skin scales. They are a common source of allergy in, e.g., Scandinavia, where their major habitat is in beds. Previous studies show that in drier environments the house dust mite occurrence is lower, and persons with dust mite allergy have fewer symptoms during the winter when the indoor relative humidity (RH) is low. There have also been attempts to alter the microclimatic conditions in beds to reduce the house dust mite occurrence. The microclimatic conditions in beds have been studied both in field measurements and by modeling but there is still a lack of knowledge of how the hygrothermal material properties of the mattress and bedding affect the environmental conditions for the house dust mites. This paper presents diurnal temperature and RH variations in mattresses and beddings under normal use measured for two different mattress types. The climatic results from the beds have been compared to microclimatic requirements that govern the house dust mite activity levels. This study is a part of a multi-disciplinary project aiming to find technical solutions for reduction of house dust mites in bedrooms by environmental control.

1. Introduction

House dust mites (HDM) are a common source of allergy in, e.g., Scandinavia where their major habitat is beds. HDM are small (<0.5 mm) animals and the microclimatic conditions of their habitat is therefore essential for their distribution and activity. A number of previous studies have shown that in drier environments the HDM occurrence is lower and persons with HDM allergy have fewer symptoms during the winter season when the indoor relative humidity (RH) usually is lower. A comprehensive literature survey (Wadsö and Svennberg 2005) shows that the climatic conditions needed to be able to control HDM activity are more complex and does to a high extent involve both RH, temperature and exposure periods. It is therefore important to have knowledge about the normal RH and temperature variations in beds during use.

The microclimatic conditions in beds have been studied both in field measurements (Cunningham 1998) and by modelling (Cunningham 1999; Pretlove, Rideley et al. 2001; Cunningham, Roos et al. 2004). Still there is lacking knowledge about the differences between different bed systems and how their different material structure affect the microclimatic conditions in the bed.

The objective of this study was two-folded: to increase the knowledge of the temperature and moisture conditions in beds during use in relation to the microclimatic requirements for HDM and to confirm the usefulness of novel measuring equipment for microclimatic measurements in the indoor environment. This paper presents the diurnal temperature and RH variations in mattresses and beddings under normal use measured for two different mattress types. We also describe the characteristics of the measuring equipment.

2. Materials and Methods

2.1 Measuring equipment

The requirements for the measuring equipment were that it should not impose discomfort for the persons sleeping in the beds and it should be robust enough to stand friction from moving persons. It had also to be rather inexpensive as several measurement points are needed to map the microclimate in a bed. To meet these requirements a combined temperature and RH sensor connected to a logger device that can be operated in a “stand-alone” mode was built in the electronics workshop at the School of Civil Engineering, Lund Institute of Technology.

The combined temperature and RH sensor (see Fig. 1) was made from an RH sensor and a thermistor. The RH sensor type has previously been used by Baker, Hunter et al. (2004). The thermistor used was a commercial precision resistance-temperature matched thermistor with a temperature measurement accuracy of $\pm 0.2^\circ\text{C}$ for a 0 to 70°C temperature range. The time constant for the thermistor is 10 s in air.

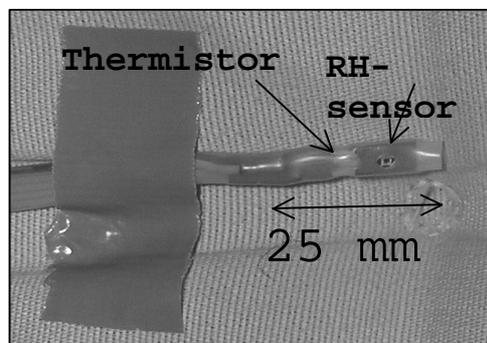


FIG. 1: The combined temperature and RH sensor mounted on a mattress.

The RH sensor (Honeywell HI-3610) is a commercially available polymer capacitive sensor with an on-chip integrated signal conditioning. The sensor has an accuracy of $\pm 2\%$ RH for the complete non-condensing interval and a maximum hysteresis of $\pm 1.2\%$ RH. The time constant in slow moving air is 15 s.

A data logger (HgmLogger) has been used to record the temperatures and RH every 5 minutes. The logger has 16 channels and can store 64000 data values. The logger can be used connected to a PC as well as in “stand-alone” mode.

2.2 Measurement set-up

In this field study two beds in two bedrooms in the same house were used for measurement of diurnal temperature and RH variations. Both rooms are placed on the second floor and have the same orientation. The basic furniture and the quantity of moisture buffering materials are the same in both rooms, only the bed type differs, see the section “Mattress and bedding materials” below. The area and volume of each room is 10 m^2 and 25 m^3 respectively.

In each measurement series 8 combined RH and temperature sensors, as described above, were used. One sensor was placed in the center of the room approximately 2 m above the floor (sensor 8), one sensor was placed underneath the lath support in the bed (sensor 7) and six sensors were placed in the bed (sensors 1-6) as shown in Fig. 2. In the evaluation it was found that the RH sensor in sensor #4 had a permanent failure. These results are omitted in the results presented in this paper. The temperature and RH was monitored every 5 minutes for 4 days. Time zero was set at the start of the first sleeping period in the study, approximately at 9 pm. Each sleeping period lasted for 9 – 10 hours.

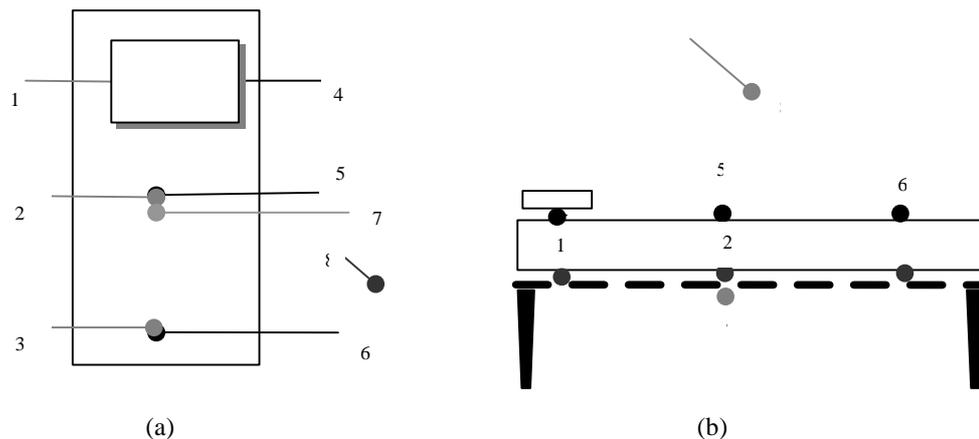


FIG. 2: The placement of the sensors is shown from above (a) and from the side (b). Note that for Bed 1 the mattress studied is on top of an interior sprung mattress and sensors 1, 2 and 3 are not in contact with the wooden laths.

The beds were occupied by two young persons – a female for Bed 1 and a male for Bed 2. They are of the same body size and have approximately the same body mass. In this study there were no measurements made to take into account the differences in sleeping pattern and individual moisture and temperature production.

2.3 Mattress and bedding materials

Bed 1

The bed is an interior sprung mattress (170 mm thick) with an overlay mattress (70 mm thick). The sprung mattress is supported by a bedstead with 70 x 19 mm wooden laths (60 mm spacing). The overlay mattress has a 40 mm polyether foam core which is covered on both sides with 15 mm wool wadding. The duvet has a helically crimped polyester fiber batting with a polyester/cotton cover fabric. The pillow is filled with polyester hollow fiber balls and also has a polyester/cotton cover fabric. The bottom sheet, duvet cover and pillow case are made of 100% cotton plain weave fabric. The space (260 mm high) underneath the bed was empty.

Bed 2

The bed is a 120 mm polyether foam mattress with a 100% cotton cover. The mattress is placed in a bedstead with wooden laths (66 x 19 mm with 60 mm spacing) and has no overlay mattress. The other bedding is identical to the one used in Bed 1. The space (270 mm high) underneath the bed was occupied with plastic boxes.

3. Climatic requirements for House Dust Mites (HDM)

HDM are small (<0.5 mm) animals related to ticks and spiders and they have developed means of inhabiting dry environments like beds and carpets of our homes. HDM have five developmental stages, some of which are very desiccation resistant. Unlike larger animals that get moisture for their survival from drinking and eating, HDM have the possibility to absorb water vapor directly from the air. They do this by excreting a salt solution that flows in a furrow on the outside of their bodies. At 20°C this method of taking up water from the air works down to approx. 58% RH, often referred to as the critical equilibrium humidity (CEH); below CEH the salt solution dries out.

Keeping the RH below 58% is thus one method of eradicating house dust mites, but this RH must not be exceeded at any time. Only one hour of high RH may be enough for the mites to replenish their body water supply to survive until the next day's high humidity period. This is one major problem with the control of house dust mites. A better control strategy involves both RH and elevated temperature, as house dust mites

do not like high temperatures. For example does the lowest RH at which they can absorb water from the air increase as the temperature increases. They will also be killed if the temperature is increased, e.g., to 45°C for 40 minutes. However, it should be noted that the allergen molecules are very stable and may remain active for a long time in an indoor environment.

4. Results and discussion

The climatic conditions (RH and temperature) of the rooms have corresponding diurnal variations. Bed 1 shows a good agreement between the climate under the bed and in the room center. Bed 2 shows a higher RH and a lower temperature under the bed compared to the room center. The vapor content diagram shows that these differences are due to the temperature dependency of the RH. See Fig. 3.

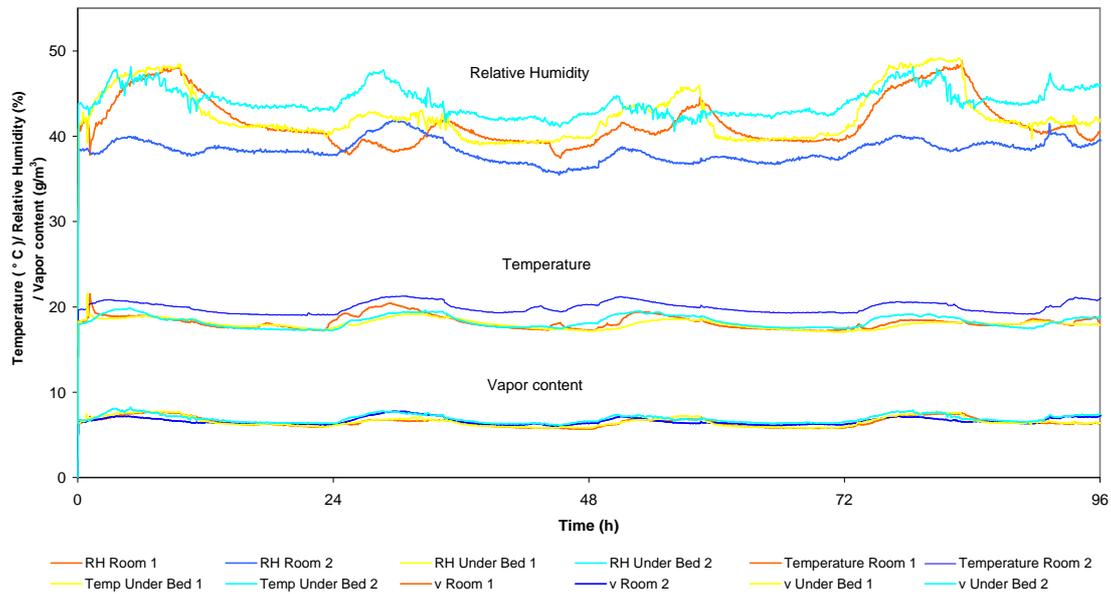


FIG. 3: The indoor climate for Room 1 and 2 during the measurement period.

4.1 Temperature

The temperatures for Torso-top (Fig. 5) and Leg-top are essentially the same for Bed 1 and Bed 2 and show good agreement with previous field measurements (Cunningham, 1998). There are differences seen in temperature fluctuations in the head region that may be due to individual sleeping patterns.

The set of temperatures Torso-under is lower for Bed 2 compared with Bed 1, see Fig. 5. This was expected as the thickness of the mattress in Bed 1 is only 58 % of the mattress thickness in Bed 2, and the mattress in Bed 2 provides more thermal insulation. (Note that “Torso-under” is not the same measuring point as “Under bed”.)

In Fig. 4 the insulation effect of the underlying spring mattress in Bed 1 is shown. This can be seen in the negative temperature differences at the end of each sleeping period, due the slower cooling under the mattress in Bed 1. This pattern is not seen for the mattress in Bed 2 which is exposed more directly to the room temperature on the bottom side of the mattress.

The effect of making the bed and putting the bed cover on is seen in Fig. 5. The morning after the second sleeping period Bed 1 was not made, it then follows the same cooling pattern as Bed 2 (not made during the measuring period).

The temperature on the surface of the bed during occupancy is approximately 35°C and correlate well with the human skin temperature (Holmér, 2004).

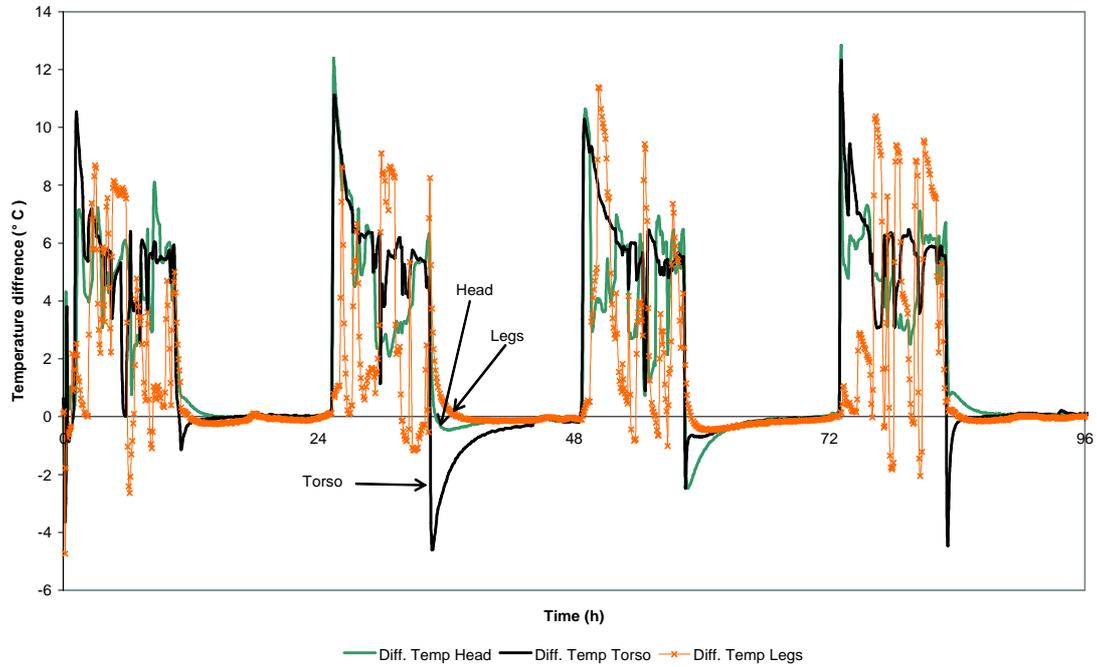


FIG. 4: Temperature differences (Top-Under mattress) for Bed 1.

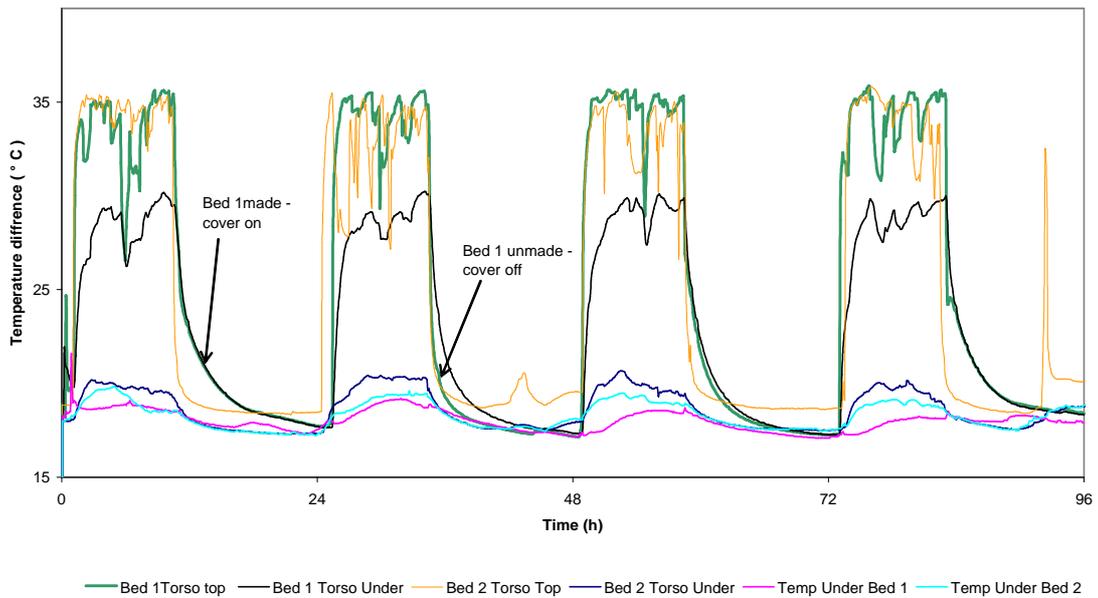


FIG. 5: Temperature comparison between Bed 1 and Bed 2 – for the torso region showing among other things the thermal effect of having the bed cover on or not.

4.2 Relative humidity

The results from the RH (RH) measurements are hard to interpret, mainly because of the large fluctuations. These fluctuations are most probably due to the movement of the sleeping persons. Both beds show RH lower than expected, this is most evident for Bed 1 that barely reaches 58% RH believed to be the lowest critical RH for HDM growth (CEH). In Bed 1 the RH variations follow the same pattern as the temperature variations. The RH variations for Bed 2 show an RH distribution that does not follow the sleeping periods as closely as Bed 1. These diurnal RH variations emphasize the importance of the temperature variations have on the microclimate of the bed (Fig.6).

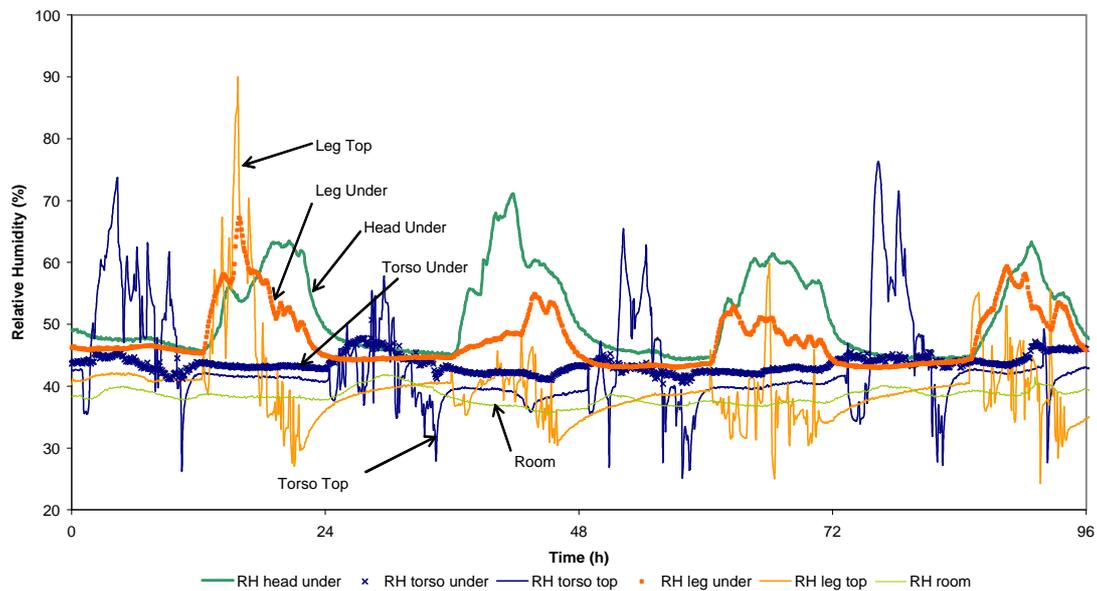


FIG. 6: The variation in RH for Bed 2.

4.3 Vapor content

The vapor content variations during the sleeping period are similar for both beds if the top of the mattress is considered. As expected the bottom of the mattress in Bed 2 show less variations and follow the vapor content variations of the room. As for the RH, the vapor content results for Bed 2 suggest moisture redistribution during day-time which is not found for Bed 1 where the vapor content for both top and bottom of the mattress is approaching the room vapor conditions.

Also for the vapor content the impact of not making the bed is seen for Bed 1 at the end of sleeping period 2, the bed approaches the room vapor conditions quicker when left unmade and without bed cover, see Fig. 7.

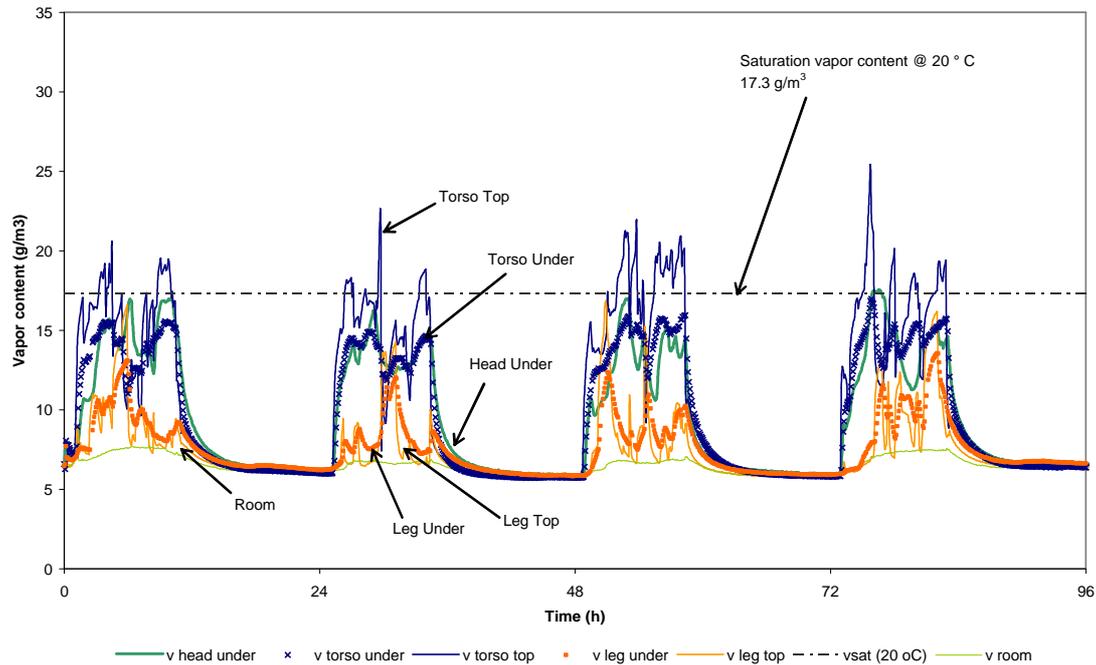


FIG. 7: The variation in vapor content for Bed 1.

5. Conclusions and future research

The results from the bed measurements show that bed systems with different material combinations give noticeable differences in the measured microclimatic conditions for the beds during use. The temperature during the sleeping period increased significantly under the sleeping person while the RH had a more modest increase. There were considerable differences in the RH variations during daytime (no occupancy) between the two beds. This could be of importance to consider when trying to control or eradicate the HDM in the bed.

Further investigations regarding the importance of sleeping pattern and individual moisture production needs to be done. More research regarding the hygrothermal material properties could provide a platform for a better understanding of the microclimatic variations in beds during use. There are several challenges ahead in how to determine these properties for these lightweight and compressible materials.

The combined temperature- and RH-sensor together with the logger showed to be working well and did not give the sleeping person discomfort due to bumps etc.

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