



The effect of sub-floor heating on house-dust-mite populations on floors and in furniture

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Abstract. It is well known that dehydrating conditions for house dust mites can be created by simply raising the temperature, causing loss of body water and eventually death. Thus, it can be expected that conditions for dust mites are less favourable on floors supplied with sub-floor heating. This was examined in a study of 16 houses with sub-floor heating and 21 without. The pattern of changes in air humidity and temperature on the floors was investigated and compared to known data of the tolerance of dust mites. Also the resident mite populations were compared. Floors with sub-floor heating had, on average, fewer mites, but the difference with unheated floors was small. It was remarkable that mite numbers were also lower in upholstered furniture. Another important observation was that some houses with sub-floor heating had high mite numbers, indicating that this type of heating is compatible with a thriving mite population. Temperature and humidity conditions of heated floors may allow mites not only to survive, but also to remain active in winter. A moderate increase in temperature, a moderate decrease in (absolute) air humidity, or a combination of both, will suffice to keep the humidity all winter below the Critical Equilibrium Humidity, the level of air humidity that is critical for mite growth and reproduction, hence for allergen production. However, it is argued that measures to suppress allergen production by house dust mites are likely to be far more effective if taken in summer rather than in winter.

Introduction

The importance of house dust mites as producers of house dust allergens is well known (Colloff et al. 1992; Lovik et al. 1998). Beds, carpeted floors and rugs are the most important habitats for these mites. It is conceivable that the temperature on floors has a strong influence on the living conditions for dust mites, because the relative humidity (RH) is known to be vitally important and RH depends on temperature. When the RH drops below the so-called ‘critical equilibrium humidity’ (CEH), dust mites are unable to extract water vapour from the air to compensate for losses of body water through evaporation (Arlian and Veselica 1981). The CEH-value of house dust mites, expressed in %RH, is higher at higher temperatures. The RH itself decreases with increasing temperature. Thus an increase of temperature will soon lead to desiccating conditions for dust mites, i.e. $RH < CEH$. Based on these considerations it may be expected that sub-floor heating (SH) will

create unfavourable conditions for mites living on the floor. However, it is not certain whether this will lead to extinction of the mite population or to a lower level of dust mite allergens in floor dust. Firstly, the exact conditions on heated floors throughout the day are unknown. Secondly, the SH is used only during the winter. Thirdly, certain species of allergenic house dust mites, namely *Dermatophagoides farinae* and *D. microceras*, are able to survive for many months at extremely low humidity, albeit in a dormant state, in which they do not reproduce, grow or produce allergens (de Boer 1998).

In the present study the humidity and temperature on floors as well as the dust-mite populations were studied in houses with SH and in comparable houses with conventional heating (CH)

Methods

Recruitment of co-operating households and inclusion criteria

In the city of Purmerend (The Netherlands, 52.30 °N, 4.56 °E) neighbourhoods were selected where SH was known to be relatively common. A total of 250 inhabitants were asked to co-operate. Roughly one third of them agreed and from these 37 were selected. Selected houses had a living room on the ground floor with a smooth type of floor, furnished with a rug which had been on that floor for at least three years. Observations were restricted to this rug and to the upholstered furniture, if present and older than three years. Through a questionnaire some additional information about the home was obtained. Sixteen of the selected houses had SH and 21 had CH. Some recordings of temperature and humidity were made in the home of the investigator. Two of the volunteers withdrew their co-operation before the end of the study and three replaced the rug. Thus, a complete set of data was obtained in the autumn of 1998, but in the spring of 1999 only 32 dwellings could be sampled, 12 with SH.

Measurements of temperature and humidity and calculations

After the heating had been on for at least 2 h, two flexible, needle shaped temperature sensors (length: 50 cm, diameter: 1.5 mm; Testo 0602.5792, Lenzkirch, Germany) were inserted underneath the rug. To find the coolest places, especially on heated floors, the probes were shifted systematically between replicate measurements. Finally one measurement was done on top of the carpet (TTL in Table 1) above the site where the lowest temperature was recorded underneath (TUL in Table 1), using the same probe.

Dataloggers (Testostor 175-2, Testo, Lenzkirch, Germany) were used to make records (every 15 min one observation) of RH and temperature on the floors. The instruments (dimensions: 77 × 45 × 25 mm) were placed on the floor, either on the rug or on a small piece of carpet material, most often against the wall. A spread-

Table 1. Temperatures underneath and on top of a rug on floors with or without sub-floor heating in 36 dwellings (December 1998 - February 1999)

		TUL (°C)	TUH-TUL (°C)	TUL-TTL (°C)
Conventional heating N = 21	average	16.9	0.3	-1.3
	highest *	20.4	0.9	-0.1
	lowest **	13.3	0.1	-5.3
Sub-floor heating N = 15	average	21.6	0.6	+1.0
	highest *	26.9	2.4	+4.2
	lowest **	18.7	0.1	-1.7

*TUL: Temperature Underneath; Lowest temperature from series of 5-10 measurements underneath the same rug (°C); TUH: Temperature Underneath; Highest temperature from series of 5-10 measurements underneath the same rug (°C); TTL: Temperature on Top, above the site of TUL (°C); * highest measured value of TUL among 21 and 15 dwellings with and without SH respectively; ** lowest measured value of TUL among 21 and 15 dwellings with and without SH respectively*

Table 2. Simultaneous measurements on floors of houses with or without sub-floor heating. RH: Relative humidity; CEH: Critical equilibrium humidity for dust mites

Period	Duration (hours)	Dwellings	% of time that RH>CEH	
			Sub-floor heating	Conventional heating
08/02-09/02	30	SH22/CH18	0.0	0.0
16/02-19/02	73	SH24/CH03	0.0	0.0
18/02-22/02	95	SH37/CH15	0.0	0.0
19/02-24/02	117	SH35/CH19	0.0	3.6
24/02-01/03	116	SH25/CH14	1.9	0.0
25/02-01/03	96	SH23/CH00	4.7	82.2
01/03-05/03	99	SH27/CH11	98.2	32.0
01/03-05/03	87	SH34/CH12	14.5	14.2
08/03-12/03	101	SH36/CH09	4.4	91.1
09/03-12/03	71	SH32/CH10	0.0	76.4
11/03-15/03	104	SH29/CH10	17.0	15.5
16/03-23/03	157	SH28/CH01	0.0	100.0
19/03-23/03	98	SH26/CH05	0.0	0.0
07/04-12/04	119	SH31/CH06	99.8	99.6
12/04-16/04	92	SH30/CH00	0.0	34.5

sheet program (Excel 7.0) was used to process the data. The CEH value at any temperature was estimated, as described previously (de Boer and Kuller 1997), by interpolation based on published data concerning *D. farinae* (Arlian and Veselica 1981). The CEH is expressed in %RH. Thus the associated absolute humidity (AH) can be calculated (Buck 1981) as well as the difference with the actual AH, revealing the change in AH that would be needed to create desiccating conditions at the same temperature (' Δ AH-needed' in Table 3). The temperature change that would be needed to create desiccating conditions at the same AH (' Δ T-needed' in Table 3) was found by trial and error, increasing the temperature by small increments until the CEH is reached.

Acarological analysis

To collect dust a Moulinex Compact™ vacuum cleaner was used at 700 Watt. Rugs were vacuumed with an ordinary floor nozzle for 1.5 min./m². Furniture was vacuumed for exactly 4 min., covering roughly 1.5 m², using an ALK nozzle (ALK, Groningen, The Netherlands). The total amount of dust was sieved (mesh 1 mm) and the sieved fraction was weighed. A sub-sample of approximately 0.05 g was taken and weighed accurately, rinsed in a 50 µm sieve using a detergent solution and washed into a Petri dish (diameter 85 mm, with grid bottom) using 70% ethanol. After all the ethanol had evaporated, 8 ml of 85% lactic acid was added and the dish was placed overnight in a stove at 70 °C. Then mites were counted, using a dissecting microscope at 25x magnification and dark-field illumination. The first

Table 3. Frequency of coincidence of the daily maximum value of {RH-CEH} with the maximum of the absolute humidity (AH) and with the minimum temperature (T) during 1–6 consecutive days (midnight to midnight). For each of the 1- to 6-day periods, it was calculated by how much the temperature had to be increased (ΔT -needed, with unchanged AH) and by how much the AH had to be reduced (ΔAH -needed, with T unchanged) in order to depress the relative humidity (RH) below the critical equilibrium humidity (CEH) for house dust mites, at the time when the value of {RH-CEH} was at its peak. CH00-CH21: Conventional heating; SH22-SH37: Sub-floor heating

Dwelling	Dates (1999)	Frequency of coincidence of daily maximum of {RH-CEH} with:				Change needed to get below the CEH		
		AH-maximum (days/total days)	T-minimum (days/total days)	{RH-CEH}-maximum (%RH)	ΔT -needed (°C)	ΔAH -needed (g / kg)		
CH00	03/02-09/02	0/5	0/5	+11	2.7	-1.2		
CH18	09/02-10/02	0/2	0/2	-5	-	-		
CH21	12/02-14/02	2/3	0/3	+1	0.3	-0.1		
CH17	10/02-14/02	2/5	0/5	-9	-	-		
CH03	17/02-18/02	2/2	0/2	-2	-	-		
CH15	18/02-21/02	1/4	0/4	-6	-	-		
CH19	20/02-23/02	2/4	0/4	+7	1.8	-0.8		
CH00	26/02-28/02	2/3	0/3	+14	3.3	-1.3		
CH14	25/02-28/02	1/4	0/4	-5	-	-		
CH12	02/03-04/03	2/3	0/3	+4	1.2	-0.6		
CH11	02/03-04/03	1/3	0/3	+3	0.9	-0.4		
CH00	07/03	0/1	0/1	+13	3.0	-1.4		
CH07	03/03-07/03	0/5	0/5	+12	3.0	-1.5		
CH08	06/03-09/03	4/4	0/4	+12	3.0	-1.3		
CH09	09/03-12/03	3/4	0/4	+7	1.8	-0.8		
CH10	10/03-14/03	4/5	0/5	+13	3.3	-1.6		
CH00	13/04-15/04	2/3	0/3	+7	1.8	-0.8		
CH06	08/04-11/04	2/4	0/4	+22	5.1	-2.7		
CH05	20/03-24/03	2/5	0/5	-2	-	-		
CH01	17/03-22/03	1/6	0/6	+23	5.1	-2.3		
SH22	08/02	0/1	0/1	-11	-	-		

Table 3. Continued

Dwelling	Dates (1999)	Frequency of coincidence of daily maximum of {RH-CEH} with:			Change needed to get below the CEH		
		AH-maximum (days/total days)	T-minimum (days/total days)	{RH-CEH}-maximum (%RH)	ΔT -needed ($^{\circ}C$)	ΔAH -needed (g / kg)	
SH24	16/02-18/02	0/3	0/3	-10	-	-	
SH37	19/02-22/02	0/4	2/4	-12	-	-	
SH35	20/02-23/02	1/3	0/3	-9	-	-	
SH25	25/02-28/02	3/4	0/4	+1	0.6	-0.2	
SH23	26/02-28/02	1/3	0/3	+1	0.3	-0.1	
SH34	02/03-04/03	3/3	0/3	+5	1.2	-0.4	
SH27	02/03-04/03	2/3	0/3	+7	1.8	-0.5	
SH32	09/03-11/03	1/3	0/3	-6	-	-	
SH36	09/03-11/03	2/3	0/3	+2	0.6	-0.2	
SH30	13/04-15/04	3/3	0/3	-28	-	-	
SH31	08/04-11/04	1/4	0/4	+19	4.2	-2.4	
SH26	17/03-22/03	2/6	0/6	0	-	-	
SH28	17/03-22/03	0/6	1/6	-6	-	-	
SH29	12/03-15/03	1/4	0/4	+11	2.7	-0.4	

25 mites, if present, were transferred to a microscope slide and embedded in Marc André solution (Krantz 1978) for microscopic examination. No attempt was made to distinguish *D. microceras* from *D. farinae*. These were all classified as *D. farinae*, read: '*D. farinae*-group'. For each specimen it was noted whether it was complete or not. A specimen was classified as 'complete' if the tarsus of every leg was present and undamaged.

Statistical evaluation

For testing differences in mite density nonparametric tests were applied (Mann-Whitney U-test and Spearman's test). For a more detailed examination of various subgroups a two-way ANOVA was applied to the log-transformed mite density values (either $\ln(x)$ or $\ln(x+1)$). In 19 of the autumn samples the mite numbers were so low that an extra sub-sample (~ 0.05 g) was drawn to obtain a more accurate estimate of the mite density. Invariably the agreement in mite densities between the two sub-samples was found to be good (X^2 -test).

The occurrence of *Dermatophagoides pteronyssinus* (Dp) relative to the numbers of *D. farinae* (Df) was examined by calculating the ratio $Dp/(Dp+Df)$, i.e. the proportion of Dp among all the *Dermatophagoides* mites identified in a sample. A deviation of this proportion from 0.5 was taken as evidence that either Dp or Df dominated. Fisher's exact test was applied for comparing the frequencies of houses where Dp dominated the acarofauna, ignoring samples with equal numbers of Dp and Df.

Results

Temperatures and humidity

On the coolest places underneath the rug, temperatures on heated floors were on average 4.7 °C higher than on floors without sub-floor heating, but sometimes a lower temperature was recorded on a heated floor than on some unheated floors. Among unheated floors those made of wood were usually warmer than the ones with tiles (Mann-Whitney U test, $0.02 < p < 0.05$, two sided). There was no discernible relation with the temperature outside at the time of measurement, indicating that floor temperatures are strongly buffered against weather changes. Local differences in temperatures underneath the same rug (TUH-TUL in Table 1) were somewhat greater on heated floors than on unheated floors, but still rather small (0.1–2.4°C). On the coolest places on heated floors the temperature on top of the rug was on average 1°C lower than underneath it. On unheated floors it was on average 1.3 °C higher (Table 1).

From each house at least one record of 4–8 d of RH and temperature was obtained, between 3 February and 11 April 1999. One example is shown in Figure 1. The typical gradual decrease of temperature, absolute and relative humidity during

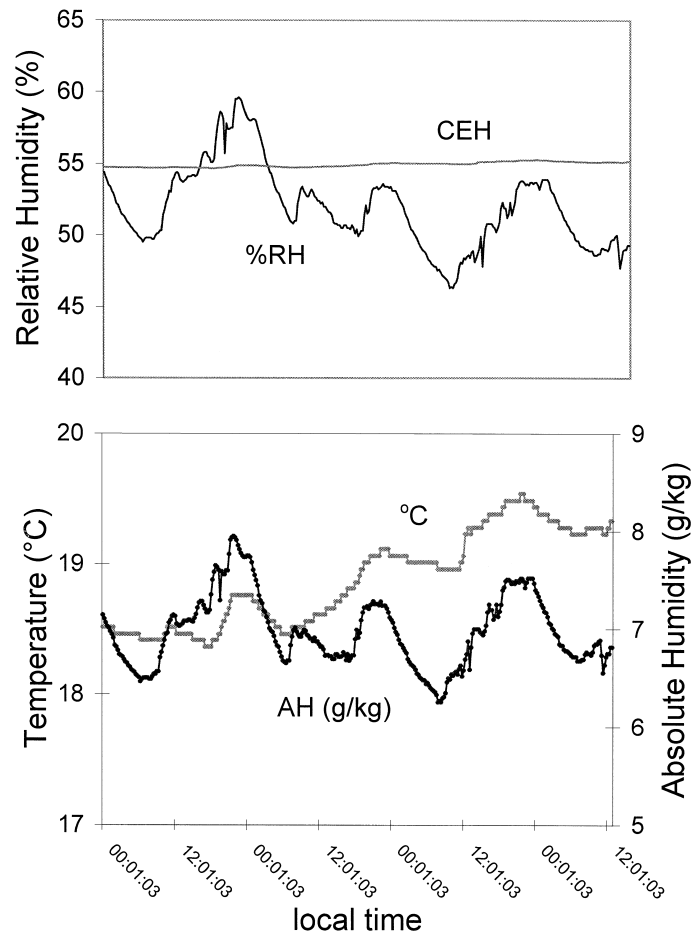


Figure 1. Changes of temperature (°C) and humidity (%RH) during 3.5 d (March 2–5) on a living room ground floor with sub-floor heating (dwelling SH21). AH: absolute humidity; CEH: critical equilibrium humidity for dust mites.

the nights can be seen in this graph. Both in houses with and without SH, the RH on floors can be above or below the CEH for several days continuously. A direct comparison of indoor climates between the two groups of houses is complicated by the ever changing weather conditions. However, where records of RH and temperature were made simultaneously in a house with SH and one without it, a direct comparison was possible (Table 2).

It turned out that the duration of RH exceeding CEH - a measure of suitability for dust mites - was 6× higher and 4× lower in houses with conventional heating. For five pairs of houses this duration was the same: in both houses RH never exceeded CEH (4×) or RH always exceeded CEH (1×). Indoor humidity often cycles with a 24 hr period, with RH exceeding CEH for only a few hours per day, if at all

(Figure 1). It is interesting to examine at what time of the day the value of {RH-CEH} is at its maximum. In Table 3 it can be seen that this often coincides with the time of the day that the AH is at its peak (viz. in 53 of 128 d in total). Daily maximum {RH-CEH} almost never coincides with daily minimum temperature (only in 3 of 128 d). Thus the AH is a much better predictor of the suitability of humidity conditions for mites, than T. Very often, however, it is the combination of AH and temperature that determines whether or not mites can take up water vapour from the air.

In Figure 2 it can be seen that the quantity {RH-CEH} reaches maximum values during times of the day with activity inside the house and not during nightly hours when everybody is asleep. Table 3 also shows the hypothetical temperature increase that would be needed to depress the RH below the CEH (' ΔT -needed') at the time of maximum {RH-CEH}, assuming that the AH remains unchanged. The effect of such a temperature increase would be that the RH remains below the CEH all the time. The actual temperatures that would be required are on average 19.3 °C (s.d. = 1.5) and range from 15.8 °C (CH00, 14-04-1999) to 22.5 °C (SH31, 11-04-1999). It is important to remember that this concerns the conditions on the upper surface of the rug, which is the coolest refuge for mites on a floor with SH. Table 3 also shows the hypothetical decrease of AH that would be needed to depress the RH below the CEH (' ΔAH -needed'), assuming that the temperature remains unchanged. The required AH was in most cases below the AH of the outside air. That means that increased ventilation could in principle have the desired effect. By combining increased ventilation (or dehumidification) with an increase of the floor temperature, it would probably be easier to keep the RH below the CEH.

Mite populations

Mite numbers in floor dust are clearly higher in autumn than in spring (Table 4). Houses with relatively high mite numbers in spring tended to have relatively high numbers in autumn as well (Spearman's test, $n=32$, $p<0.001$, two-sided). Floor dust from houses with SH contained on average lower numbers of mites, but only in spring is the difference statistically significant ($0.02<p<0.05$, Table 4). If a house is vacated during office hours, this probably affects the pattern of air humidity and temperature during the day. However, a comparison between the 8 CH houses that were usually vacant during office hours, with the 12 other CH houses, reveals no indication that occupancy during the day affects mite numbers (Mann-Whitney U-test, two-sided, $p>0.10$, both for mites/g and mites/m²). When the houses that were vacant during office hours are nevertheless excluded, to obtain more similarity between the group with SH and with CH, the differences in mite numbers are no longer significant (Table 4). To examine whether the number of inhabitants of a house affects the mite numbers, a 2-way ANOVA was done ("CH vs SH" x " ≤ 2 inhabitants vs >2 inhabitants", excluding the houses that are vacant during office hours). The influence of the number of inhabitants must be either absent or only small ($p>0.50$, both in spring and in autumn and for mites/g as well as mites/m²).

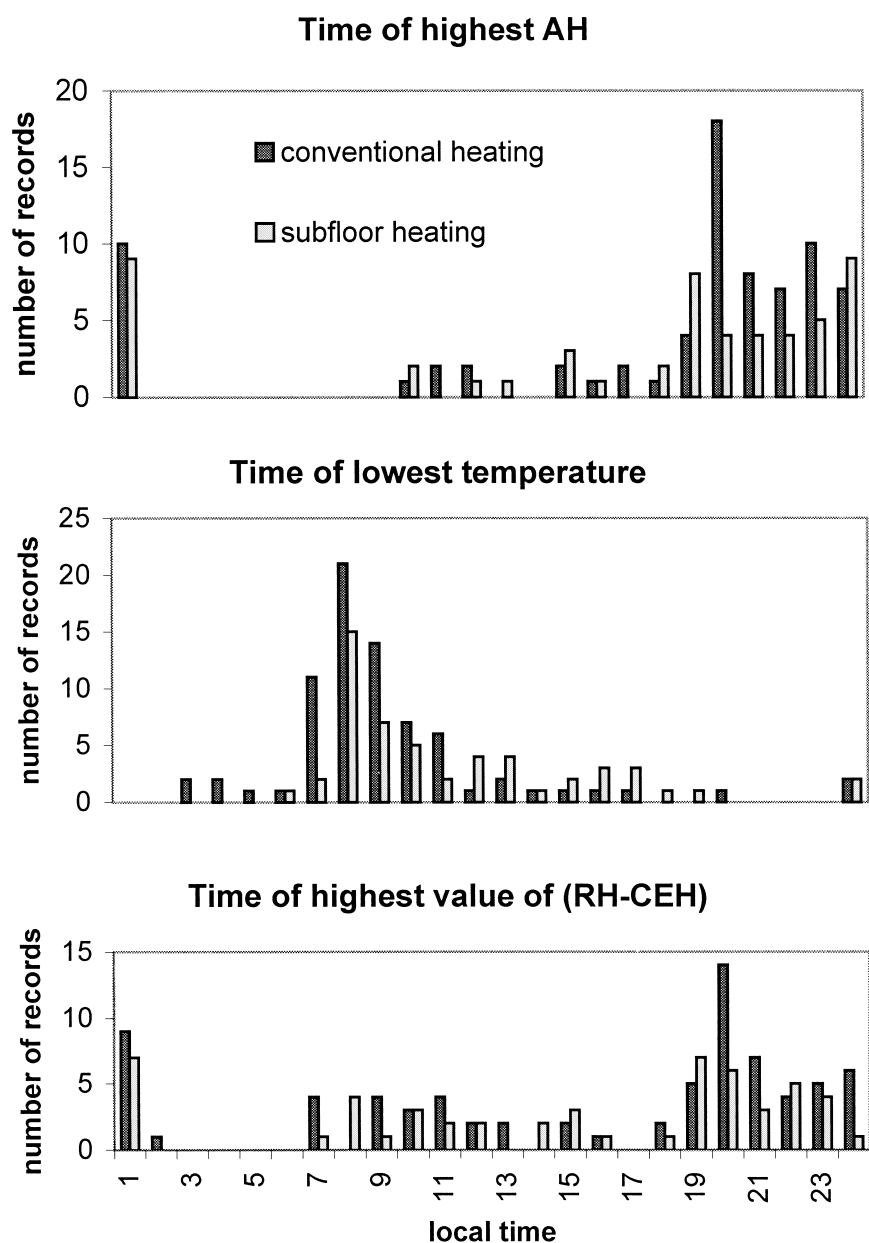


Figure 2. Records of the time of day when absolute humidity (AH) and the value of {RH-CEH} reach their maximum, and when temperature is at its minimum (in total 128 d recordings; dwellings with conventional heating: 75 d, with sub-floor heating: 53 d). RH: relative humidity; CEH: critical equilibrium humidity for dust mites.

Table 4. Mites per m² of a rug and per 4 min vacuuming of a couch in houses with and without sub-floor heating

Dust sample	Conventional heating		Sub-floor heating		P*
	N	Average (Range)	N	Average (Range)	
Rug, Spring All houses	20	521 (10-3124)	12	153 (0-722)	0.02<P<0.05
Rug, Spring Houses, not vacant during office hours	12	384 (10-1856)	11	154 (0-722)	P>0.10
Rug, Autumn All houses	21	1473 (90-4909)	16	1275 (3-10744)	P>0.10
Rug, Autumn Houses, not vacant during office hours	13	1667 (90-4909)	15	1293 (3-10744)	P>0.10
Couch, Au- tumn All houses	14	424 (10-1296)	12	87 (0-292)	P<0.01
Couch, Au- tumn Houses, not vacant dur- ing office hours	8	432 (10-1296)	12	87 (0-292)	P = 0.02

* Mann-Whitney U-test, two-sided N = Number of houses

The influence of the presence of a cat or a dog, examined in the same way, must also be small or absent (invariably $p>0.20$).

SH seems to have some influence on mite numbers in floor dust, although not very strong. Some houses with SH had quite high mite numbers, for instance the highest number of mites per m² (10744) was recorded in a house with SH.

If it is true that *D. farinae* (Df) is better adapted to survive dry winter conditions than *D. pteronyssinus* (Dp), it may be expected that Df is more common in houses with SH. In floor dust collected in spring, 29% of all identified *Dermatophagoides* mites were Df; 27% (n = 264) in CH houses and 41% (n = 41) in SH houses. In floor dust collected in autumn, 32% were Df; 34% (n = 308) in CH houses and 31% (n = 238) in SH houses. In furniture dust, also collected in autumn, as much as 57% of all identified *Dermatophagoides* mites were Df; 69% (n = 213) in CH houses and 32% (n = 100) in SH houses. Both in the CH and in the SH group, some houses were found where Df turned out to be the dominant species. If Df was the dominating species in floor dust, it was usually also dominating in furniture dust collected in the same house in the same season (Fisher's exact test, one sided, $p = 0.036$). When Dp was dominating in floor dust collected in spring, it was often

Table 5. Proportion of *Dermatophagoides* mites that were undamaged ('complete') and possibly alive when collected from rug or couch, in autumn or spring

	Proportion complete (Total number)					
	Autumn/Rug		Autumn/Couch		Spring/Rug	
	CH	SH	CH	SH	CH	SH
<i>Dermato-phagoides</i> sp.	0.23 (79)	0.17 (54)	0.15 (20)	0.00 (8)	0.14 (14)	0.00 (3)
<i>Dermato-phagoides pteronyssinus</i>	0.19 (204)	0.27 (165)	0.32 (66)	0.51 (63)	0.14 (190)	0.04 (24)
<i>Dermato-phagoides farinae</i>	0.12 (104)	0.14 (73)	0.27 (148)	0.45 (31)	0.22 (74)	0.06 (17)
Total	0.18 (387)	0.22 (292)	0.27 (234)	0.45 (102)	0.16 (278)	0.05 (44)

also dominating in floor dust collected in autumn in the same house (Fisher's exact test, one sided, $p = 0.002$). Houses where Df dominates the acarofauna in spring occur more frequently in the SH group, but there is no statistical significance (Fisher's exact test, one sided, $p = 0.159$). In autumn Df-dominated houses are even underrepresented in the SH-group (Fisher's exact test, one sided, $p = 0.913$ for floor dust and $p = 0.926$ for furniture dust).

If a mite specimen is undamaged, this is evidence (but no proof) that it was alive when it was collected. Table 5 shows that in spring relatively few undamaged specimen were collected from floors with SH as compared to floors without SH (X^2 -test, $p=0.04$). This indicates that in spring, i.e. by the end of the heating season, relatively few live mites were present on floors with SH.

Discussion

Houses with SH were found to have fewer mites than houses with CH, although the difference was only small. At least four published studies give information on mite faunas on heated floors. These studies were done in Korea and Japan (Sugawara et al. 1996), Australia (Brown 1996) and Germany (Schata et al. 1990; Kuehr et al. 1994). One of these German studies concerns a survey of mite allergen concentrations in mattress dust from as many as 1050 family homes (Kuehr et al. 1994). SH was only one of many characteristics examined for their possible influence on dust mite allergen concentrations using multiple regression analysis. Less of the mite allergen *Der p 1* was found in mattress dust from houses with SH than from houses with CH, but the amounts of *Der f 1* were similar. Unfortunately the type of floor (smooth or carpeted) was not mentioned or considered as a possible confound-

ing factor. In the present study a much smaller group of houses was investigated, but these were selected for having a smooth floor furnished with a rug of >3 yr. old. In two other studies, one in Germany and one in Australia (Brown 1996; Schata et al. 1990), it was also found that mite numbers were on average lower in houses with SH, but at least some houses did have a mite population on a heated floor. Interestingly, in all three studies, as well as in the present study, it was found that mite numbers or allergen concentrations in other mite habitats than the floor, namely in furniture upholstery and in beds, were also lower in houses with SH than in houses without SH. Perhaps the microclimate in beds and couches may be somewhat different when the heat source is underneath. Traffic of mites within and between homes may also have an impact (Mollet and Robinson 1995; Tovey et al. 1995). In this connection it would be interesting to examine whether houses with smooth floors, known to be devoid of dust mites, have fewer mites in beds and in furniture than houses with carpeted floors.

Do house dust mites survive the winter on heated floors? We found evidence of very low numbers of live mites in spring on floors with SH. Also Schata et al. (1990) reported some live mites on heated floors during the winter. However, it is possible that these mites were recent immigrants from other sites in the house. We know that *D. farinae* can survive many months at continuously low RH (<CEH, de Boer (1998)). Indeed, houses with SH harboured relatively more *D. farinae*, but the difference is small and variable and on some floors with SH *D. pteronyssinus* dominated. It should be remembered that, besides the heated floor, other important habitats for mites existed in the houses, such as beds, stuffed furniture and unheated floors.

The present study also provides information on the patterns of RH and temperature on the floors. For every record it was determined whether the RH was above or below the CEH. The CEH-value for every temperature was interpolated, based on the CEH-values at 15, 20, 30 and 35 °C, determined for a strain of *D. farinae* (Arlian and Veselica 1981). For *D. pteronyssinus* the CEH-values have been determined at only two temperatures so far. At 16 °C it was found to be 56–58% (de Boer et al. 1998), i.e. considerably higher than the CEH of *D. farinae* (52.6% by our interpolation method). The same *D. pteronyssinus*-strain at 20 °C had a CEH of 58–60% (de Boer and Kuller 1997), which is also higher than the CEH of *D. farinae* (55% by our interpolation method). Thus it seems that *D. pteronyssinus* has higher CEH-values than *D. farinae*, although inter-strain variability is possible. For the interpretation of the present microclimate observations it is best to consider the lowest CEH-values found for either of the *Dermatophagoides* species. Domestic activities during the day, e.g. cooking or bathing, often caused the air humidity to rise above the CEH-value, providing hydrating conditions for mites both in houses with and without SH. It is known that only a few hours of high RH (>CEH) per day are sufficient for house dust mites to maintain water balance (de Boer and Kuller 1997; de Boer et al. 1998). Sometimes the RH remained below the CEH continuously for several days, both in SH and in CH houses. This is undoubtedly influenced by weather conditions. Laboratory studies have shown that it takes several weeks to exterminate a *D. pteronyssinus* population through desiccation (de

Boer and Kuller 1997; de Boer et al. 1998). Since weather conditions required to achieve this do not usually last that long in the Dutch temperate, maritime climate, the physical conditions in winter on heated floors may allow mites not only to survive but also to remain active. On the other hand the living conditions on heated floors were near the tolerance limit and it is not surprising that live mites are scarce in winter. A rise of floor temperature by a few degrees or a reduction of indoor air humidity, or a combination of the two, could suppress RH below the CEH continuously throughout the winter. This seems practically feasible, since the measures needed may be acceptable and attainable.

However, it is doubtful and even unlikely that uninterruptedly dry (<CEH) winter conditions will guarantee a low allergen concentration, because mites of the Df-species group could easily survive many months at very low humidities and start to reproduce and produce allergen again massively when conditions improve in spring (Ellingsen 1975; Sakaki et al. 1990; Sakaki and Suto 1991; Suto and Sakaki 1990; Suto et al. 1992). In countries like The Netherlands, Germany, Denmark, UK and Sweden, houses can be found where concentrations of dust mites or mite allergens are very low. This is usually associated with low indoor humidity (Kuehr et al. 1994; Hart and Whitehead 1990; Korsgaard 1983; Munir et al. 1995; Strien et al. 1994; Wickman et al. 1991). To explain this association it has been postulated that the mite population dies out in these houses through desiccation during the winter (Korsgaard and Iversen 1991). Also for controlling mites by reducing air humidity the focus usually has been on the winter period rather than the summer. In winter AH is much lower so that desiccating conditions can be accomplished more easily than in summer. But if it is not feasible to kill mites in winter a reduction of the RH may well have a much stronger effect in summer. The rates of reproduction and allergen production are continuously low in winter, not only because of the low RH but also because of the low temperatures on floors and in unheated bedrooms. During summer, the rate of allergen production can be high, leaving much room for down-regulation. Reducing RH, even if it remains above the CEH, will reduce the rate of reproduction, growth and allergen production (Gamal-Eddin et al. 1983a, 1983b). Allergens will accumulate only if the rates of mite reproduction and allergen production exceed the rates of removal.

It is a pity that the summer conditions have been largely ignored by experimentalists who tried to control mites by changing the indoor climate. For instance, Custovic et al. (1995) examined the effect of dehumidifiers, placed for three months in English houses (one per house) during the winter period. No effect on mite numbers or allergen concentrations was seen, but the decrease of humidity was also very small. In another trial, mechanical ventilation with heat recovery and dehumidification during the winter period, failed to bring the allergen levels down, although RH between January and May was on average 13% lower than in the control houses (Niven et al. 1999). In contrast, Cabrera et al. (1995) examined the effect of dehumidifiers (one per bedroom) on the Canary Islands, where conditions are conducive for mite growth probably year round. A strong and statistically significant effect was seen on the concentrations of *Der p1* and *Der p2/f2* in mattress dust.

SH creates less favourable conditions for house dust mites, but it does so probably at the wrong time of the year, and in only some of the mite-infested sites in a house. SH is usually combined with a smooth floor, which is more suitable for the home of an allergy patient than carpet. Thus, the instalment of SH helps to reduce allergen exposure, but it is not, by itself, sufficient to eliminate house dust mites, certainly not in a temperate, maritime climate.

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