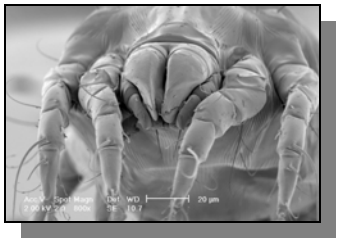

The Environmental Control of House Dust Mites. Validation of a Combined Hygrothermal Population Model

Progress Summary Report
July 2005

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1.0 INTRODUCTION

Inhaled allergens derived from house dust mite (HDM) faeces play a major role in allergic disease, especially in asthma. The number of people affected is rising throughout Europe (and indeed worldwide), now impairing the health and quality of life of a substantial proportion of children, as well as many adults, and placing a significant burden on health services.

It is known that temperature and humidity play an important role in house-dust mite physiology. Room conditions are important because dust mites have a unique mechanism for taking up water, which involves secreting a salt solution from the upper part of their front legs to their mouth. This mechanism enables mites to take up water from the room air. If the room conditions become dry this salt solution crystallises, the mechanism stops and hence the mites dehydrate and eventually die. Consequently, there is considerable interest in reducing mite populations in dwellings by controlling the internal environment.

This EPSRC-funded project builds upon the completed EPSRC-funded project *A Hygrothermal Model for Predicting House Dust Mite Response to Environmental Conditions in Dwellings*. The original EPSRC-funded project successfully developed a sophisticated hygrothermal population model of house dust mites in beds. This new 2-year follow-up project, also funded by EPSRC, improves the model and tests it in homes around the UK.

The original EPSRC funded project found that mite numbers are heavily influenced by environmental conditions in homes, and by the heating regime, ventilation and humidity in particular. It produced a prototype model – the most advanced of its kind – that can assess how different building features and patterns of occupant use affect these conditions, and therefore house dust mite numbers.

The new research project represents the next step in developing the model for use in devising anti-mite strategies for a range of UK house types. It includes laboratory monitoring of mite population growth in a range of conditions, which will generate data essential to the effectiveness of the model. To validate the model, the project also involves a field study comprising houses across the country. The fieldwork involves monitoring temperature and humidity in bedrooms and beds, as well as mite populations found in the beds.

This progress report summarises the work undertaken in the first year of the project which has focused on the development of appropriate laboratory and field methods and refining the models.

2.0 MODELLING AND COMPUTER SOFTWARE

A whole suite of software is now available for simulating the response of individual mites and of whole mite populations to various micro-climates. The software simulations are written in such a way as to allow easy reconfiguration by the user to many different scenarios.

As well as beds, the fast 3D micro environment simulator (LECTUS) can potentially be applied to any soft furniture found in a building such as carpets and sofas. The crucial input of room conditions can be supplied by sensors from a real room, or from a building simulator. Occupant behaviour can also be tailored to the particular requirements of a room in question. For bedrooms and beds this would be sleeping pattern (hours in bed), moving during sleep, size of the person, beds made, or not made in the morning, etc. We are confident that we have the correct heat and vapour transfer algorithms and the simulation is able to reproduce the results of trial runs with reasonable accuracy. However there is space for improvement, which will come with better information on the material properties of bedding.

A simple steady state hygrothermal bed model (BED) that predicts monthly average conditions of temperature and humidity within beds is also being tested through the fieldwork study.

The mite population simulator (POPMITE) can take its micro-environment input directly from LECTUS, or from sensors placed inside real beds, carpets or sofas. It then simulates mite population response in these environments. POPMITE currently uses data from the behaviour of mites held at constant conditions to predict the response of mite populations to typical micro-environments, where conditions can change rapidly. Nevertheless, we are confident that the underlying algorithms for modelling the mite life cycle are sound. We do get good agreement from trial runs with constant micro-climate conditions and preliminary results from field trials with mites held in changing conditions are very encouraging. However the calibration data is very limited, with large gaps especially at low relative humidities. Fresh calibration data will be available soon and this will be used to recalibrate POPMITE to give the best possible predictions.

In addition to these three main packages (LECTUS, BED and POPMITE) there are numerous tools and simulations which provide further detailed insight into different aspects of the mite. These include the movement of mites through bedding and the water uptake and loss mechanisms of mites, and its relationship to the egg laying rate. These tools will enable the calibration data to be better interpreted, ready to be used by POPMITE.

3.0 LAB WORK: MITE PHYSIOLOGY

The aim of this work is to provide calibration data on the life cycle of house dust mites for the POPMITE model. Adult reproduction and immature development of house dust mites are under investigation at a range of temperature and relative humidity combinations. Specifically, detailed data on adult pre-reproductive period,

reproductive period, fecundity, longevity and mortality, as well as egg, larva and nymph development times and mortalities is being provided for the model.

Preliminary work suggested differences in performance of long-established laboratory mite cultures compared to 'wild' mite cultures recently extracted from house dust. In addition, performance on optimised laboratory diets differed from that on more natural diets including skin scales and dust. Therefore we are using recently collected 'wild' *Dermatophagoides pteronyssinus* and *Dermatophagoides farinae* cultures for our experiments. These cultures are maintained in fluctuating temperature and relative humidity conditions on a diet of skin scales and house dust. In addition, for our experiments a diet of skin scales and mattress dust is being used. In doing so our aim is to obtain calibration data for POPMITE that is more representative than existing physiological data.

4.0 LAB WORK:

Relative humidity and temperature constantly change within the home and the mattress. The house dust mite population model (POPMITE) is currently based on data for mite growth and survival under steady state conditions, i.e. constant relative humidities and temperatures. The aim of these experiments, now under way, is to provide a matrix of laboratory data to assess how daily changes in temperature and relative humidity affect mite population growth. “Wild” (i.e. not laboratory bred) mites are being kept at a low base level of relative humidity (32%) over six weeks and then exposed to high levels of relative humidity (75%) for 0, 1, 2, 4, 8, 12 and 24 hours daily. In each case, their growth and survival is being assessed at three different temperatures.

In addition, house dust mites kept at a base level of favourable humidity (75%) will be exposed to 12 hour changes in temperature and again their rates of growth and survival will be assessed. The temperature experiments will be expanded at a later stage, when there is more room in the incubators.

Because the incubators required for the above experiments arrived several months later than promised, there has been time to carry out some other experiments to investigate how mites move in response to different relative humidities and temperatures.

As well as being interesting in their own right, all of these laboratory experiments are providing vital data for the model. They are also helping us to understand the results of the detailed mite bed experiments in which house dust mites, contained within special mite and allergen proof cages/ envelopes, are placed in a number of locations within mattresses.

The detailed field experiments are progressing well. An initial trial following on from the Phase 1 experiments has taken place in which mite cages were placed in triplicate in 13 locations in the mattress, at 3 depths under zones A, C and D and 4 depths under zone B; see figure 1. Mite cages were also placed at 2 locations in the bedroom. The mite and allergen proof cages/ envelopes again worked well; none ruptured. There were some problems with the sensors on the surface of the bed, these have been modified and a further trial is taking place.

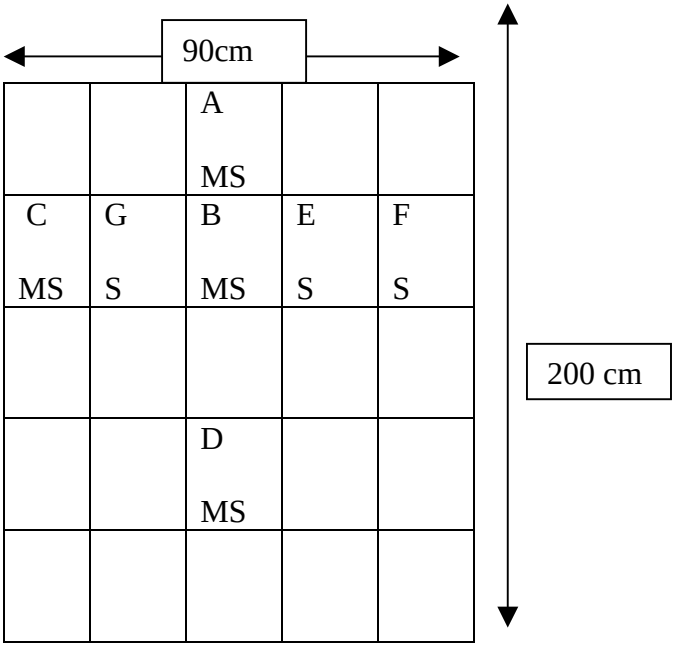

Figure 1: Distribution of mite cages (M) and sensors (S) within a mattress, each cell is 18 × 40 cm in plan

5.0 FIELDWORK

The main objective of the fieldwork is to monitor hygrothermal conditions occurring in housing and beds, as well as mite survival rates. These results will then be compared with model predictions. More specifically, temperature and humidity are monitored in the participants' bedrooms for a period of six weeks; and detailed building and occupant information is also gathered. Live encapsulated mites are placed in the participants' beds, as well as sensors monitoring the conditions to which the mites are exposed. In this way the fieldwork study will give the opportunity of using real beds as "incubators" where mite growth can be examined in relation to realistic transient conditions.

A target of 15 houses (Series 1 houses) has been set, where the bed equipment (i.e. encapsulated mites plus sensors) is placed underneath the sleeper's chest. This location was chosen as it represents the most varied hygrothermal conditions in the bed, on a 24-hours cycle. A further 4 houses (Series 2 houses) are to be studied in more detail, with the bed equipment placed in several locations within the mattress, in a 3-dimensional array.

So far, 9 'Series 1 houses' have been visited (5 in Birmingham; 2 in Southampton; 1 Liverpool; 1 Newcastle). One participant only accepted the bed sensors, but no mite bags. However, House 1 had mite bags 3 times, once with a double set of bags/sensors (under the chest and edge of bed). The encapsulated mites placed in the participants' houses have so far all died, except in one house (10 out of 11 cases). This was expected, since the low relative humidities resulting from the sleeper's temperature are not favourable to mites at this location. It nevertheless presents a test for POPMITE to predict.

	Average Measured			Popmite Version 4			Popmite Version 5		
House Number	Eggs	Juv.	Adults	Eggs	Juv.	Adults	Eggs	Juv.	Adults
1, First Round	0	0	0	0	8.2	0	0	0	0
1, Second Round	0	0	0	0	4.2	0	0	0	0
1, Third Round, Chest	0	0	0	0	5.9	0	0	0	0
1, Third Round, Edge	0	0	0	0	24.1	0	0	0	0
2	0	0	0	0	47.4	0	0.11	1.21	0
3	0	0	0	20.4	92.9	24.3	51.97	14.37	6.41
4	0	0	0	0	41.9	0	0.02	0.03	0
5	0	0	0	0	6.5	0	0	0	0
6	2	51	1.3	46.8	0	10.8	0.06	0.17	0
7	0	0	0	0	6	0	0	0	0
8	0	0	0	0	7.2	0	0	0	0

Table 5.1: Series 1 Houses, Comparison of Predicted and Measured Survived Mite

Table 5.1 shows the agreement between measured and predicted mites alive after the 6 weeks. The results of two different versions of POPMITE (4 and 5) are shown, to illustrate the continued improvement in understanding and modelling of mite physiology. The discrepancies between the data and POPMITE version 4 are significant, and can be attributed to the low temperatures to which some mite bags were exposed to when posted back by the participants. This was not modelled well in version 4. Version 5 shows a marked improvement in predicting the measured results as it now models low temperatures correctly. There are still discrepancies: the predictions for houses 3 and 6 over and under estimate the mite populations respectively. The causes of these discrepancies are being investigated, but the probable cause is the scarcity of the calibration data on which the population model is based. This problem will be solved when more calibration data become available from the lab work, as well as from the fieldwork.

As regards the validation of the bed hygrothermal model Lectus, at present the model assumes that in the surface areas immediately under the body the temperature is constantly 34 degrees centigrade and the vapour pressure excess (i.e. moisture difference between bed and room) is 1000 Pa.

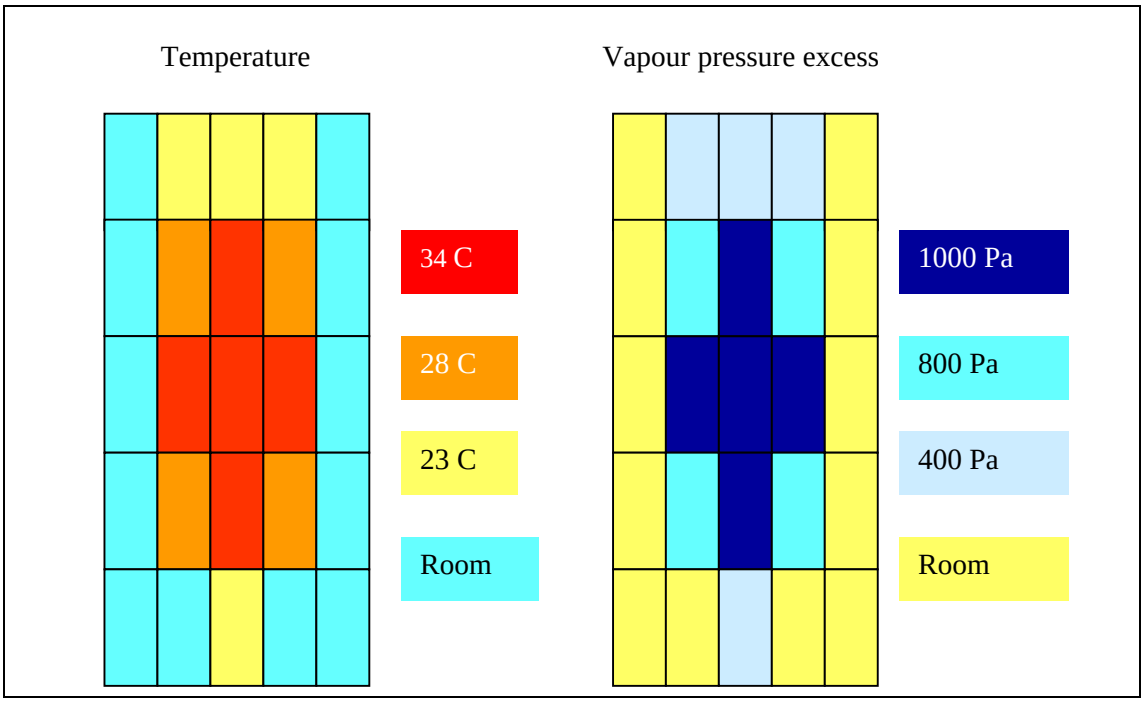

Figure 5.1 Boundary conditions adopted in Lectus

In 'Series 1 houses' the sensor is placed on the mattress in the area corresponding to the occupant's chest. The monitored results showed that when the bed is occupied the sensor readings are not constantly giving 34 °C and 1000 Pa vapour pressure excess, as during the night the participant can move in the bed, away from the sensor. It was not considered feasible to ask participants to keep diaries of their sleeping times over a 6 weeks period. This meant that at times it is hard to interpret the monitoring results and establish whether the participant was still in bed (but away from the sensor), or if the participant had temporarily left the bed at the moment the sensor values were recorded.

Table 5.2 shows a summary of the hygrothermal conditions measured under the participant's chest during sleeping times. The latter have been defined as those periods of times when the bed temperature is at or above 28 degrees C. The table shows that the average temperature and vapour pressure excess are lower than the values currently assumed in Lectus. This could be due to the sleeper moving in the bed. The type of clothing used by the participants when sleeping could also play a role. However, these results are also partly determined by the 28 °C value adopted as a threshold to establish when the person is in bed. For the next Series 1 houses, it may be useful to ask participants to keep a sleep diary for the first 3 days. Nonetheless, the results so far seem to indicate that the effect of people moving in the bed might have to be taken into account for the boundary conditions adopted in Lectus. The detailed monitoring in the new 4 'Series 2 houses' should help solve some of the issues regarding the sleeper's movement and clothing.

	Temp. Bed (° C)	RH Bed (%)	Vapour Pressure Bed (Pa)	Temp. Room (° C)	RH Room (%)	Vapour Pressure Room (Pa)	Vapour Pressure Excess (Pa)
Average	31.6	46.0	2130.2	17.8	65.6	1322.1	808.1
Max	34.9	83.6	4414.9	22.7	90.4	1752.0	2907.4
Min	28.0	25.6	1042.0	14.2	44.9	759.9	34.5
STD	1.7	9.0	476.7	1.6	9.7	174.5	378.5

Table 5.2 Measured hygrothermal conditions in monitored beds (under the chest), during sleeping times.

A pilot study for 'Series 2' houses was carried out in March-April 2005. Most mites died, which may have been due to the adverse time of the year. The pilot study highlighted some problems with the durability of the sensors when exposed to body weight and movement over a 6 weeks period. These problems are currently being addressed.

The data so far gathered from the 9 'Series 1' houses is currently in the process of being analysed using the BED3 model. Finally, it should be mentioned that dust samples from beds and carpets are also sampled in the participants' bedrooms. The samples will be tested to assess Der p1 levels, once all the dust samples have been collected from all the houses.

5.0 CONCLUSIONS

Considerable progress has been made since the start of the new EPSRC project.

1. We now have a very sophisticated suite of computer models which can easily be reconfigured to look at a range of interesting problems with different levels of complexity in both population modelling and built environment. This enables easy testing of the model against a range of laboratory and field study data and in turn has helped to design the most appropriate research methodology for field experiments.
2. A clear methodology has been developed for laboratory determination of the impact different environmental conditions have on the different stages of the life cycle of mites. This has included developing laboratory techniques to work with "wild mites" fed on natural diets of skin scales and dust. The main laboratory tests are now being undertaken.
3. A detailed methodology for monitoring in the field has been developed which includes encapsulating populations of mites within a bed and monitoring the environmental conditions that they are exposed to. Eleven cases have so far been studied and the results compared with model predictions. This work is ongoing.

The research is therefore generally progressing well an should deliver the key results originally proposed.

We have also had considerable success in disseminating the work of the team. Research results are currently being disseminated to the academic community via 8 papers plus two presentations at a World Health Organisation meeting of experts(see Appendix A). In addition we have successfully reached a wider non-academic audience through attendance at an EPSRC exhibition and a subsequent press release. We have madeover 33 contacts with the media, resulting in printed articles and interviews appearing in a wide range of media formats (see Appendix A).

Discussions with the Steering Committee and other stakeholders has indicated the importance of extending the research beyond the original scope of the project. The team is therefore preparing a new bid for EPSRC funding to undertake the following work:

1. Assessment of environments other than beds, e.g. carpets toys etc.
2. Consideration of young children and the environments they create.
3. Demonstration and dissemination through a two day international conference of the results of the research programme.

We would welcome further suggestions.

APPENDIX A: Dissemination

Papers in Submission Process

1. Phillip Biddulph *et al*., "Predicting the population growth of the house dust mite *Dermatophagoides pteronyssinus* (Acari: Pyroglyphidae) in variable hygrothermal conditions".
2. David Crowther *et al*., "A simple model for predicting the effect of hygrothermal conditions on populations of house dust mite *Dermatophagoides pteronyssinus* (Acari: Pyroglyphidae)".
3. Ian Ridley *et al*., "A model to predict the hygrothermal conditions experienced by House Dust Mites within beds".
4. Stephen Pretlove *et al*., "A Steady State model for predicting hygrothermal conditions in beds in relation to house dust mite requirements".

Proposed New Papers

1. Phillip Biddulph *et al.*, "Accurate Prediction of the Physiological response of individual House Dust Mites to a changing habitat with the PHYMITE simulation program".
2. Barbara Hart *et al.*, "Reproduction and development of laboratory and wild mites: influence of culture and diet".
3. M. Ucci *et al*., "Validation of a model predicting the hygrothermal conditions experienced by house dust mites within beds".
4. M. Ucci *et al.*, "Comparison of a simple and a complex model for the prediction of hygrothermal conditions experienced by house dust mites within beds".

Exhibitions/Presentations

1. "A celebration of UK engineering research and innovation", 17 November 2004, Showcase of UK research funded by the UK's *Engineering and Physical Sciences Research Council*.
2. Presentations at the first meeting of experts to help prepare a planned WHO publication on "Urban Pests and Health" (May 2005):
    - Dr David Crowther "How buildings and building use can contribute to allergy and asthma".
    - Toby Wilkinson "Dust mite biology, control and management - potential for adverse public health effects"

OTHER MEDIA COVERAGE

Printed

1. Mark Peplow, "Lie-ins keep beds clear of mites", Nature.com, 19 November 2004.
2. Mark Prigg, "How billions of bed bugs warm to our climate", Evening Standard, 24 November 2004.
3. Robin Yapp, "Good news! Not making your bed kills the dust mites!", Daily Mail, 18 January 2005.
4. "Untidy beds may keep us healthy", BBC News Online (Health), 18 January 2005.

Interviews (Dr Stephen Pretlove)

Tuesday 18 January

5. BBC Radio Five Live
6. BBC Radio Manchester
7. BBC Radio Oxford
8. BBC Radio Scotland – Newsdrive
9. BBC Radio Wales
10. Classic Gold Radio
11. Radio Jackie
12. ABC Radio (Australia)
13. Radio New Zealand

Wednesday 19 January

14. 1.30pm Spin 103.8 (Dublin)
15. 3.00pm Vienna Austrian Broadcasting Corporation
16. 4.35pm BBC Three Counties Radio
17. 7.45pm Radio 2UE Sydney (Mike Carlton breakfast show)

Thursday 20 January

18. 11.00am Radio WTOP, Washington (TBC)

Other coverage gained

19. Sky News text
20. BBCi (text service)
21. The Scotsman
22. Surrey Comet
23. Kingston Informer
24. Radio Jackie

25. Cabinet Maker magazine
26. Innovations Report

Expression of interest

27. Discovery Channel Canada
28. BBC London
29. BBC Radio
30. BBC1 News
31. ITN News
32. BBC London Today
33. Radio 3AW