A HYGROTHERMAL MODEL FOR PREDICTING HOUSE-DUST MITE RESPONSE TO ENVIRONMENTAL CONDITIONS IN DWELLINGS

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ABSTRACT

House-dust mite antigens are a major contributor to allergic sensitisation. Since temperature and humidity are crucial to house-dust mite physiology, there is considerable interest in reducing mite populations by controlling the indoor environment. A multidisciplinary team of building scientists and entomologists has been formed to develop a prototype hygrothermal model that simulates the dynamic interaction between the mite's micro-environment within bedding and the room environment, based on laboratory tests and field study measurements. Combined with a dynamic model of mite physiology, this can be used to predict mite response to changes, e.g. in building fabric, the heating/ventilation regime or occupant behaviour. In this way the most effective and applicable measures for mite control can be determined. The model will be developed for potential use by practitioners as a simplified predictive tool.

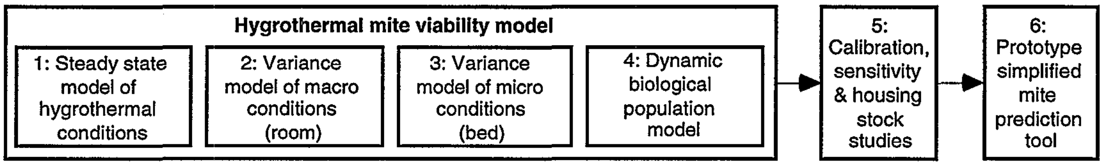
INTRODUCTION

Antigens derived from the faeces of the House-Dust Mite (HDM) are thought to be one of the major causes not only of asthma but of allergic sensitisation generally. HDM proliferation can be reduced by removing the source of food (human skin scale), e.g. with microporous bedding covers, or by killing them with acaricide sprays, heat treatments or freezing. However, such methods are costly and/or inconvenient, and tend only to be adopted as *curative* measures once symptoms have occurred. By contrast, controlling mites hygrothermally is additionally relevant as a generally applicable *preventive* approach.

HDMs require a particular combination of temperature and humidity to flourish, ideally between 75 and 85% RH, and 22 and 28 °C [1]. For example, as temperature falls, egg output slows and egg-to-adult development time rapidly increases. However, while low temperatures help to reduce mite proliferation, they do not always kill them. By contrast, low RHs do kill adult mites, and the lower the RH, the quicker they die. In winter, a well-heated and well-ventilated house can provide the dry conditions that are deadly to mites and over successive seasons (at least at higher latitudes), mite populations can be reduced to near-zero. The WHO recommend that ventilation in winter should maintain *absolute humidity* in bedrooms below 7g/kg and several studies have confirmed that mite populations can in this way be reduced dramatically and asthma symptoms alleviated [2]. However, the validity of the 7g/kg threshold has been questioned [3] and recent UK surveys have found poor correlation between absolute humidity and HDM proliferation [4]. UK bedroom temperatures are typically less than 20°C in winter, and below this temperature the simple 7g/kg rule of thumb may be less effective in ensuring that mites are denied the hygrothermal conditions they require. Average room conditions may also inadequately represent local conditions in carpets and bedding [5]. There is thus a need for a model of domestic hygrothermal conditions that can be more closely related to mite physiology. By predicting HDM response to different conditions, such a model would enable the efficacy of alternative strategies for mite control to be tested, such as changes to building fabric (e.g. improved insulation), the heating/ventilation regime and occupant behaviour (e.g. window opening habits, airing of bedding, moisture production, etc).

METHODS

There are three nested spatial zones that need to be related to each other: *ambient* conditions outside the dwelling, *macro* conditions inside the bedroom (taking account of the effect of the rest of the house) and *micro* conditions within the mite environment, i.e. bedding, carpets and upholstery. For simplicity, we are concentrating on the bed environment, being the most important, with its regular nocturnal supply of food, warmth and humidity. Whether and for how long mites remain above their Critical Equilibrium Humidity is affected by conditions in the bedroom, which in turn are affected by ambient conditions, dwelling characteristics (insulation, airtightness), the heating and ventilation regime, and occupant behaviour. It is thus essential to take account of dynamic variations over time, i.e. for complete 24-hour cycles, season by season. This is one of the key innovative aspects of the project.



Proposed model development

The starting point is the existing steady state hygrothermal model *Condensation Targeter 2*, developed by UCL and SBU for assessing the likelihood of high RH and mould growth. From relatively few data inputs, this well established model predicts mean monthly space and surface temperatures and RH. The next step is to simulate how hygrothermal conditions vary about the mean, incorporating only as much detail as is necessary to predict the impact on mite populations. Step 3 involves simulating the response of the bed microclimate to human occupation and the macroclimate of the bedroom. This will be based on field measurements in a representative sample of volunteer households, as well as climate chamber measurements involving a volunteer sleeping in an instrumented bed. In this way all the variables affecting the results (including the properties of different bedding materials, airing habits, etc.) will be identified - one of the project's most important objectives. In Step 4, a dynamic biological mite population model will be developed in collaboration with the Cambridge Medical Entomology Centre, based on the substantial literature that exists on HDM physiology.

HDM populations will be sampled during the field studies and, together with data from previous field studies, the results will be used to calibrate the model by adjustment of the input assumptions (note that it is a physics-based causal model, not a "black box" correlation model). A sensitivity study will be carried out to determine the measures likely to have most impact on mite populations, and the model will also be applied to UK housing stock data for an initial assessment of the potential benefit of alternative achievable interventions at a national scale. The final deliverable will be a protype tool for practitioners. End-user representatives are collaborating in the project to ensure that it is tailored to their needs.

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