AN INITIAL EVALUATION OF A 'BIOHYGROTHERMAL' MODEL FOR THE PURPOSE OF ASSESSING THE RISK OF MOULD GROWTH IN UK DWELLINGS

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ABSTRACT

Moulds are organisms that may be found in both the indoor and outdoor environment. Moulds play an important role breaking down and digesting organic material, but, if they are significantly present in the indoor environment they may affect the health of the occupants. A relative humidity of 80% at wall surfaces is frequently stated as the decisive criterion for mould growth and methods used to assess the risk of mould growth are often based on steady state conditions. However, considering the *dynamic* conditions typically found in the indoor environment, a better understanding of the conditions required for mould to grow would seem desirable. This paper presents initial exploratory work to evaluate and assess 'WUFI-bio' - 'biohygrothermal' software that predicts the likelihood of mould growth under transient conditions. Model predictions are compared with large monitored data set from 1,388 UK dwellings before and after insulation and new heating systems are installed ('Warm Front'), the suitability of this software as a tool to predict mould growth will ultimately be assessed. This paper presents some initial, exploratory work.

KEYWORDS: Biohygrothermal model, Mould, Relative Humidity, Moisture, Transient conditions

INTRODUCTION

The English House Condition Survey 1996, reports 14.6% of the total English stock to have mould growth (DETR 2000).

More recently a study of the mould in 1,388 fuel poor dwellings in the UK (Altamirano-Medina *et* al 2006) showed that 19.5% of dwellings had a Mould Severity Index (MSI) greater than 0 (i.e. mould in at least one room) (DETR 2000) - *see table 1*. From those dwellings, 52% presented a Relative Humidity greater than 70% for more than two hours.

	Percentage of time RH above 70%	0	1-10.	10-17.	17-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	Total	%
MSI	No mould	793	125	39	12	29	18	16	10	12	16	16	31	**1117**	**80.5**
	Mould	131	34	18	3	19	10	8	6	3	8	11	20	**271**	**19.5**
	%	48	**52**												
Total		924	159	57	15	48	28	24	16	15	24	27	51	**1388**	**100**

Table 1: Number of dwellings with mould according to the Mould Severity Index (MSI)

This criterion relates to the current Approved Document F of the Building Regulations for England and Wales (DCLG 2006), which states that:

'*the relative humidity in a room should not exceed 70% for more than two hours in any twelve hour period, and should not exceed 90%, for more than one hour in any twelve hour period, during the heating system'.*

Note that it was also found that 48% of properties having any level of mould according to the MSI did not present RH higher than 70% at any time during the period recorded.

A relative humidity of 80% at wall surfaces is generally stated in the literature as a decisive criterion for mould growth. Commonly used methods use steady state, ie monthly average, values of temperature and relative humidity to assess the risk of mould growth.

A new biohygrothermal method had been proposed by Seldbauer (Sedlbauer 2001) 'WUFI-bio' (WUFI 2005) in order to predict mould growth under *transient* boundary conditions. This is achieved via the calculation of the resulting water content in a modelled mould spore when exposed to transient conditions and comparison to the critical water content, above which the spore will germinate and mould will start to grow.

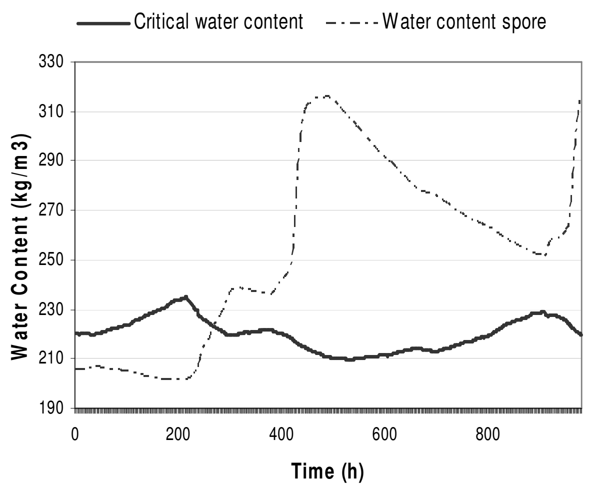

Figure 1: Predicted spore germination in a selected Warm Front dwelling

In the example, *Figure 1*, shows germination occurring when the water content of the modelled spore (dashed line) exceeds the critical moisture content solid line after 270 hours.

Some testing of the model has been undertaken in German dwellings (Krus *et* al. 2001). This current study has begun some exploratory work with the model as applied to UK dwellings – the details are presented below.

METHODOLOGY

The following methodology is an initial exploration using 'Wufi-bio' to assess the risk of mould in UK dwellings. The predictions of mould occurrence using input data, (RH, temperature, and construction details), from the 'Warm Front' database, are compared with reported mould levels.

Ext. wall material	Dwelling ID	MSI	Room	RH Avg	% RH>70%
Solid Brick	501288	11	Living room	65.82	21
			Bedroom	89.95	100
	605401	0	Living room	77.51	83
			Bedroom	77.39	99
Masonry cavity	02323912H	7	Living room	62.27	2
			Bedroom	70.35	58
	471698	0	Living room	65.03	21
			Bedroom	75.63	100
Insulated Cavity	02045639W	3	Living room	53.48	0
			Bedroom	52.78	0
	373545	0	Living room	62.13	15
			Bedroom	87.35	96

Table 2: Characteristics of the selected dwellings simulated

Dwellings characteristics

Six dwellings from the 'Warm Front' database were selected for the present study, three with reported mould (MSI>0) and three without – *see Table 2*. Three external wall constructions: solid brick wall, masonry (air cavity), and masonry (insulated cavity) were examined.

Temperature and relative humidity calculation at the wall surface

'Warm Front' database consists of hourly room air temperature and relative humidity measurements. Wufi-bio requires hourly wall surface temperature and surface relative humidity. The surface temperature of the wall was calculated from room and external air temperature using 'Wufi 2.2' (IBP 2004) a computer program for the calculation of simultaneous heat and moisture transport in multi-layer building components. The thermal conductivity, thermal mass of the wall and heat transfer coefficients at the wall surface are considered in the calculation. The surface relative humidity was then calculated using the surface temperature and the room vapours pressure.

Wufi input files, including internal and external temperature, were constructed from the 'Warm Front' database. As 'Warm Front' data in dwellings was recorded for periods of three to four weeks in winter time, in order to have "warm-up" period, a three week period consisting of the repeated first two days of measured data was used to pre-condition the wall to minimise the influence of the chosen initial wall temperature.

As internal and external air temperature and RH was available for each room, the surface relative humidity was then calculated simply via the relevant formulae (1) that consider the vapour pressure (2) and saturated vapour pressure (3) in the room and the known surface temperature.

$$SRH = SSVP / RVP \qquad (1)$$

$$RVP = RRH / 100 * RSVP \quad (2)$$

$$SSVP = ST > 0{,}610.5*EXP\ ((17.269*ST)/(237.3+ST))\ or < 610.5*EXP((21.875*ST)/(265.5+ST))) \quad (3)$$

Where:
SRH = Surface Relative Humidity
ST = Surface Temperature
SSVP = Surface Saturated Vapour Pressure
RVP = Room Vapour Pressure
RSVP = Room Saturated Vapour Pressure
RRH = Room relative humidity

RESULTS

Calculated transient surface conditions were applied in 'WUFI-Bio' in order to predict spore germination and later mould growth in both bedroom and living room of each dwelling. The results presented in *Table 2* indicate that only in 6 rooms was spore germination predicted. Those houses with external walls of solid brick have mould predicted in living room and bedroom, while mould was also predicted in bedrooms of two houses with external walls of masonry (air cavity) and masonry (insulated cavity), IDs number 471698 and 373545 respectively - *see Table 3*.

Ext. wall material	Dwelling ID	Room	WUFI -Bio		
			Average surface conditions		Mould prediction
			RH	Temp	
Solid Brick	501288	Living room	67.66	15.98	Y
		Bedroom	92.12	11.68	Y
	605401	Living room	78.01	17.07	Y
		Bedroom	77.72	14.24	Y
Masonry cavity	02323912H	Living room	67.64	20.2	N
		Bedroom	70.86	19.24	N
	471698	Living room	65.5	16	N
		Bedroom	75.5	12.1	Y
Insulated Cavity	02045639W	Living room	53.62	22.28	N
		Bedroom	52.88	22.6	N
	373545	Living room	62.58	13.3	N
		Bedroom	87.16	10.77	Y

Table 3: Prediction of mould

The air relative humidity in those 6 rooms, where spore germination was predicted, was measured to be above 70% for more than 20% of the time. However, spore germination was not predicted in other rooms where high air RH (more than 20%) was also recorded for example, in both masonry cavity dwellings. These results indicate that there is no clear relationship between the spore germination predicted during a short monitoring period and actual reported mould - *see table 4*.

Dwelling ID	Room	MSI	Prediction
501288	Living room	Y	Y
	Bedroom	Y	Y
605401	Living room	N	Y
	Bedroom	N	Y
02323912H	Living room	Y	N
	Bedroom	Y	N
471698	Living room	N	N
	Bedroom	N	Y
02045639W	Living room	Y	N
	Bedroom	Y	N
373545	Living room	N	N
	Bedroom	N	Y

Table 4: Comparison of predicted and reported mould

DISCUSSION

In this study a very small number of dwellings have been simulated and some very preliminary results only have been obtained. Nevertheless, they represent a valuable stepping stone to the possible use of this model for the evaluation of mould risk in UK dwellings. Future work will take into account the following issues:

1. The calculated surface temperature does not necessarily represent the coldest part of the wall as it was calculated using one dimensional heat flow. If a three dimensional thermal analysis package such as 'VOLTRA', (Physibel 2004b) was used instead of Wufi 2.2, transient conditions could be calculated for those coldest parts of a wall such as thermal bridges and corners.

2. The 'Warm Front' data was recorded for only a few weeks for each dwelling, during the heating season. It is limited both in terms of type of data recorded and length of the monitoring period. Consequently, additional modeling methods will be explored in order to extend this monitored data, into data representative of the whole heating season. Additionally, a new more extensive database (of dwellings surveyed and monitored in Milton Keynes, UK) (CARB 2005) will also be used in future work.

3. The mould growth noted in each of the dwellings was recorded only at one particular time during the monitoring period – no 'history' of the growth is available. Despite this the data provides a useful insight into the issue of mould growth under real conditions.

CONCLUSION

A 'biohygrothermal model' has been applied in order to predict mould growth in UK Dwellings. This pilot study developed a suitable methodology to use the biohygrothermal model with the data available in the Warm Front database.

Preliminary results suggest that there was no simple relationship found between the predicted and reported occurrence of mould. Further simulation and analysis will be done in order to assess if WUFI-bio may be used as a tool for prediction of mould growth in a realistic manner in the UK, and to establish the important variables and information, which must be present in the input database to achieve reliable predictions.

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