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Summary Continuous mechanical ventilation with heat recovery (MVHR) has been advocated as a means of controlling house dust mite. 40 houses in the Southampton area, UK, were chosen for study. 20 were fitted with MVHR systems and the remainder acting as controls. Temperatures and humidities were measured in asthmatic patients' bedrooms for a period of over one year. Measurements were also made of mite and allergen levels, indoor air pollutants and clinical changes. Analysis of these variables will be reported separately. Over the winter months the mechanically ventilated (MV) bedrooms had a mean absolute humidity of 6.75 g kg^{-1} as against 7.53 g kg^{-1} for the controls ($P < 0.001$). The World Health Organisation has suggested 7 g kg–1 as a value below which mites fail to thrive. 15 of the mechanically ventilated houses had a mean winter humidity below 7 g kg^{-1}, compared with only 3 of the control houses. Humidities were lower in leakier homes, but this was significant in the mechanically ventilated group only.

Ventilation and house air tightness: Effect on indoor temperature and humidity in Southampton, UK

F R Stephen†, **D A McIntyre**‡ MA PhD, **A Lane**† BSc, **G J Raw**§ DPhil CPsychol, **C R Wiech**§ MSc and **J Frederick**¶ BSc
†EA Technology, Capenhurst, Chester CH1 6ES
‡Indoor Climate Services, 33 Eaton Road, Chester CH4 7EW
§Building Research Establishment, Watford WD2
¶School of Medicine, University of Southampton, Level G(803), Centre Block, Southampton General Hospital, Tremona Road, Southampton SO16 6YD

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1 Introduction

1.1 Asthma and ventilation

Much asthma is caused or exacerbated by an allergic reaction to the house dust mite. The mite is to be found in nearly all homes, where it inhabits bedding and soft furnishings. Medical opinion is moving towards allergen avoidance as a means of asthma prevention. Many methods have been recommended for allergen reduction in the home and many trials have taken place. However as yet no method has emerged as universally applicable or successful[1,2]. It is known that increased levels of humidity provide a favourable environment for the growth of mites. Evidence indicates that dust mites may be controlled by maintaining a reduced indoor humidity during winter months through continuous mechanical ventilation[3,4].

Controlling house dust mites by ventilation and humidity reduction is attractive. Once a suitable ventilation system has been installed it incurs little further expense or alteration in lifestyle. The potential added advantages are good ventilation and consequent improvement in indoor air quality. As against mechanical ventilation, mechanical ventilation with heat recovery (MVHR) reduces ventilation heat loss with consequent energy savings.

A World Health Organisation (WHO) working party has proposed that a level of humidity below a moisture content of 7 g kg^{-1} is sufficiently low to inhibit the growth of mites[5]. This has been interpreted by Korsgaard[6] that if humidity levels can be kept low enough during winter the population of house dust mite will not have time to recover fully during the summer, when outside absolute humidity is higher. The WHO guideline was used as a design figure when considering the specification of ventilation systems for this trial. As more information becomes available it is likely that the limits of humidity and temperature for mite control will be refined. The review by Arlin[7] places greater emphasis on relative than on absolute humidity.

The reported studies of the use of mechanical ventilation to control dust mites have mostly taken place in Scandinavia or Northern Europe, where the winters are colder and drier than in the UK. Weather data were analysed for 14 locations in the United Kingdom, with the results shown in Figure 1[8]. The data indicate that reduction of humidity to the WHO guideline value should be possible over most of the UK. A pilot study in South Wales found a tenfold difference in dust mite concentration in bedroom carpets between houses that used mechanical ventilation and those that did not[9]. However, intervention studies, using either mechanical ventilation or dehumidifiers to reduce humidity, have not shown universal success in reducing mite population. Doubt has been raised as to the applicability of ventilation to house dust mite control in climates with winters milder than those in Scandinavia[10].

1.2 Southampton trials

A clinical trial has been set up to investigate the possibility of using MVHR in the UK to reduce the concentration of house

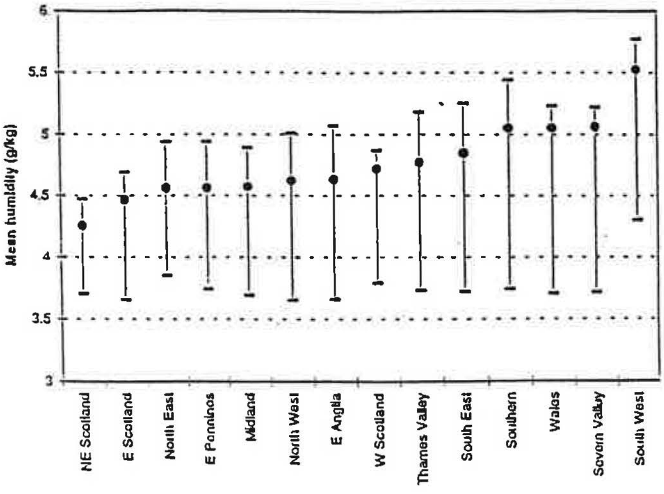

Figure 1 Mean outdoor absolute humidity over the four months January, February, March and December for 14 locations in Britain. Each line shows the mean for 1963 (low), 1967 (typical) and 1974 (high).

dust mites. This is a collaboration between the Department of Child Health, Southampton University, the Building Research Establishment (BRE) and EA Technology. The trial has monitored the progress of asthmatic patients in 40 households over a period of more than a year. Southampton University carried out allergen monitoring and clinical measurements and was the main point of contact with the patients. EA Technology was responsible for installing MVHR in 20 houses and logging temperature and humidity in all 40 houses. BRE undertook air quality measurements(11), occupant questionnaire surveys, air tightness measurements on the houses and analysis of dust samples for house dust mite concentration. The trials also investigated the effect of high-efficiency vacuum cleaners and other aspects of the indoor environment. However, each participant was encouraged not to change their lifestyle in any way throughout the period of study. This report considers only the effect of ventilation and house air tightness on indoor temperature and humidity.

2 Experimental

2.1 Selection of houses

Southampton University was responsible for the recruitment of patients from among those attending the Southampton asthma clinic. All those willing to participate were asked to complete a questionnaire about their home. The responses were analysed as to the suitability of the houses. This was confirmed by an external survey of all properties. Houses were rejected from the study if they appeared to have excessive uncontrolled ventilation (e.g. having open chimneys), used bottled gas heating appliances or were unsuitable for the installation of MVHR. The houses were assigned to experimental groups to balance their characteristics across treatment groups as much as possible. Houses were classified into four humidity bands based on mean absolute humidity measured over the preliminary period from March to May 1994. The allocation of houses into experimental groups is described in more detail in Reference 11. For this paper, the treatment groups are referred to as Group A (fitted with mechanical ventilation) and Group B (control). No purpose-provided ventilation openings or systems were present in the houses in Group B.

2.2 Ventilation system design

For this study it was decided that to provide the benefits of ventilation but minimise the disruption associated with a whole-house ventilation system, an 'upstairs' system would be installed. The main MVHR unit, containing fans and heat exchanger, is mounted in the loft space. It supplies tempered fresh air to the bedrooms and extracts moist air from the bathroom. An additional extract point is fitted in the landing; this avoids excessive extraction rates through the bathroom terminal and intercepts moist air moving up the stair well. The system therefore only requires access to the loft space for installation and no ductwork within the house is needed. A further requirement of the ventilation system was that it be capable of installation in a variety of existing properties. Evaluation to be meaningful, similar ventilation rates and conditions should be provided in all the ventilated rooms. Occupant-controlled extractor fans were fitted to extract moist air from the kitchens.

Each ventilation system consists of:

- a loft-mounted mechanical unit containing the heat exchanger and system fans
- supply diffusers, for installing in bedroom ceilings
- extract ports, for the bathroom and landing/hallway
- interconnecting ductwork in the loft
- external air inlet/outlet grill, normally mounted in soffit or gable wall
- manual boost switch for the bathroom, increasing extract by 50%
- electricity mains isolator
- an EU4 grade filter, mounted in the outside air intake duct

Householders in Group A were asked to use the ventilation system continuously and to use the boost facility when required during showering. They were also asked not to open windows during winter, but they were not prevented from doing so.

2.3 Installation and maintenance of ventilation system

Installation was controlled by the plant manufacturer. The first units were installed using rigid PVC ducting, which was insulated after installation. This proved difficult and time-consuming, especially where access was difficult at the eaves. A change was made to pre-insulated flexible ducting. This is much easier to install and has the advantage of providing a significant degree of sound attenuation. It costs more than rigid ductwork and has the disadvantages of higher pressure drop and vulnerability to damage. Neither proved to be a problem in this case. No silencer was installed. The loft-mounted mechanical unit was insulated after installation. The method of system insulation varied between houses. Where the insulation was taped over the mechanical unit, access was more difficult when replacing filters.

On commissioning, the mechanical ventilation system was set to provide an air supply of $8\ l\ s^{-1}$ for a double and $6\ l\ s^{-1}$ for a single bedroom. Air extract in the bathroom was set at twice that in the landing, to reduce spillage of moist air out of the bathroom. The system was balanced to provide a slightly greater total extract than supply rate. After commissioning, the system was switched off until the ventilation systems in all the houses were ready to be switched on.

2.4 Temperature and humidity loggers

EA Technology compared relative humidity and temperature measurements at positions near the floor, at different heights and at various locations within a room. Measurements at floor level were found to be reliable and were less susceptible to rapid variations in humidity than those taken mid-air in the centre of the room. The optimum recording interval was also determined during these tests. Scanning for ten minutes recorded events within the room accurately. It was therefore decided to use loggers mounted in a perforated aluminium case at floor level. The case is strong enough to withstand being walked on and the apertures allow free air circulation for the humidity sensor. The logger can also be moved and replaced by the householder when cleaning. The type of logger used was a Smartreader 2, manufactured by ACR. The sensors are integral with the logger and the humidity is recorded directly as relative humidity. In addition to the loggers in the test bedrooms, two loggers were used to record external outdoor conditions. The loggers were mounted on the north-facing side of two dwellings within the survey area.

They were protected from rain by mounting them in a metal cover open to the atmosphere.

Data were collected using a portable computer during visits to the homes. The disk was then sent to EA Technology where the data were transferred to a database and the results checked for consistency.

2.4 Data handling

All loggers were checked before installation and found to read within 1.5% relative humidity (RH) and to provide temperature readings accurate within 0.36 K. There were some problems with the outdoor humidity sensor when exposed to an RH above 90%. This caused the reading to drift upwards to give some readings around 100% RH. Weather data were also obtained for the Southampton region from the Southampton Weather Centre, and showed good agreement with the data obtained from the loggers.

A good standard of completeness of data was maintained, though inevitably some data were lost. Out of a total of 3293 house–weeks, plus 148 outdoor weeks, only 73 weeks' data were lost, mostly due to logger data stores becoming filled. There was very little loss from equipment malfunction. The data were processed routinely to provide a table of weekly means and standard deviations of temperature and absolute humidity for each house. This table was distributed to collaborators. Much of the analysis in this report is based on weekly mean values.

Humidity may be described as relative humidity (RH) or as absolute humidity (AH). Of the several ways of expressing absolute humidity, this report uses the moisture content g (g kg–1), measured in grams of water vapour per kilogram of dry air. The working hypothesis proposed by the WHO working party[5] is that dust mite growth is inhibited below an absolute humidity of 7 g kg^{-1}.

2.5 Measurement periods

Weeks are referred to using a standard notation W*nn*/*yy*, where a week runs from Monday to Sunday. The year 1994 runs from W1/94 commencing 3 January through to W52/94 commencing 26 December 1994. Year 1995 starts with W1/95 on 2 January 1995. Data loggers were installed in the majority of the houses during March to May 1994. All but three loggers were operational by W28/94. Ventilation systems were installed during October and November 1994. After installation the systems were commissioned and left switched off. 19 systems were switched on 9 November 1994; the remaining system on 20 November 1994 because the household were away from home from 9 November until this date. The total recording period has been subdivided as shown in Table 1. Analysis of weather records over many years[12,8] shows that the four winter months December to March inclusive have a consistently lower mean absolute humidity than the remainder of the year. These four months are analysed separately as period P3.

Table 1 Analysis periods

Description	Start and finish	Duration (weeks)	Code
Pre MV	W27/94–W43/94	17	P1
MV period	W45/94–W43/95	51	P2
Winter 94/95	W48/94–W13/95	18	P3
Summer 95	W25/95–W32/95	8	P4
Post MV comparison	W27/95–W43/95	17	P5
Total measurement	W27/94–W43/95	69	P6

Air temperature readings were compared with 30-year mean monthly values recorded by the Meteorological office at Southampton[13]. Comparable results were not available for absolute humidity and therefore the typical weather year of 1967 at Bournemouth (some 20 miles away and also on the coast) was used. The experimental period was characterised by an unusually mild and moist autumn in November and December 1994 and an unusually warm summer in 1995.

3 Results

3.1 Temperature

Weekly mean bedroom temperatures are plotted against weekly mean outdoor temperatures for Period P2 in Figure 2. Group A and Group B show similar behaviour. Above 15 °C outdoor temperature, bedroom temperatures rise steadily with increasing outdoor temperature. Below 15 °C, bedroom temperature falls only slowly with decreasing outdoor temperature. Separate linear regressions have been carried out for the data sets above and below 15 °C outdoor temperature. The best fit lines are shown in Figure 2. Analysis of covariance was used to test the hypothesis that bedroom temperatures were the same in both groups over varying outdoor temperatures. The result showed a significant difference between Group A and Group B ($P < 0.001$ below 15°C and $P < 0.05$ above), with Group A being about 0.5°C warmer than Group B. Hence the hypothesis was rejected. If the hypothesis were true, the probability of obtaining the sample of data would be less than 0.001 below 15°C, and less than 0.05 above 15°C.

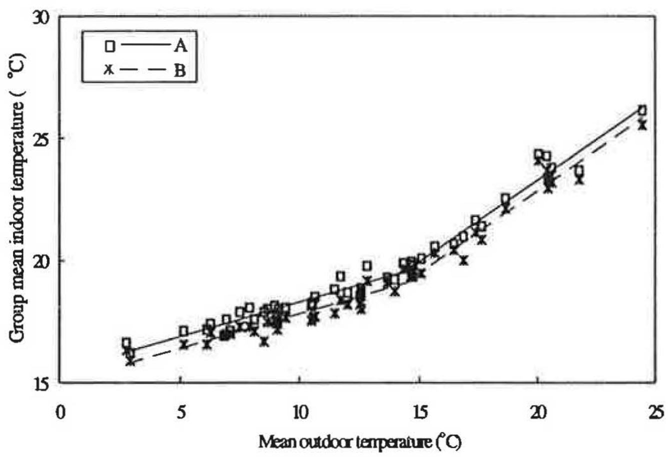

Figure 2 Weekly group mean bedroom temperatures over period P2. Separate linear regressions of bedroom temperature T on outdoor temperature T_0 were carried out above and below an outdoor temperature of 15°C, to give best fit lines $T = a + bT_0$ (See Table 2.)

Table 2 Results of regression analysis of bedroom temperature on outdoor temperature

Group	T ≤ 15°C			T > 15°C		
	a	*b*	r^2	*a*	*b*	r^2
A	15.44	0.28	0.91	9.91	0.67	0.94
B	14.98	0.28	0.90	9.43	0.67	0.92

3.2 Humidity

Figure 3 shows a sequential plot for absolute humidity. Using absolute rather than relative humidity permits a direct comparison between indoor and outdoor conditions. Table 3 shows medians and quartiles of temperature and humidity by group for the various measurement periods.

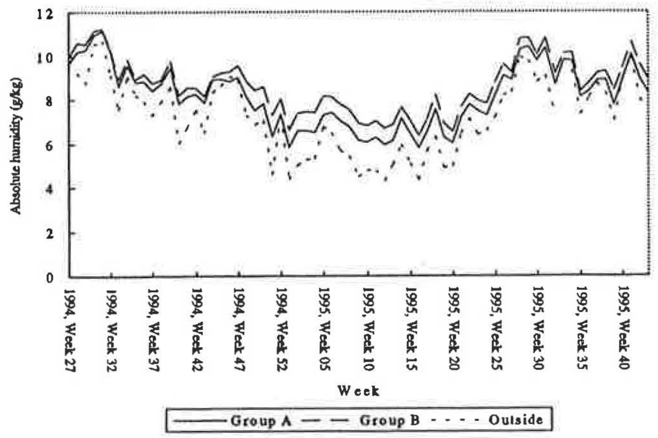

Figure 3 Weekly group mean humidities plotted sequentially over the whole study period

The hypothesis that Group A and Group B had different bedroom humidities was tested using analysis of covariance with MV as the main effect and outdoor humidity as a covariate. The results showed a significant effect of MV on bedroom humidity with $P < 0.001$, which can be interpreted as the probability of obtaining the sample data, given that there is no difference between the groups. Weekly mean bedroom humidities are plotted against outdoor humidity in Figure 4

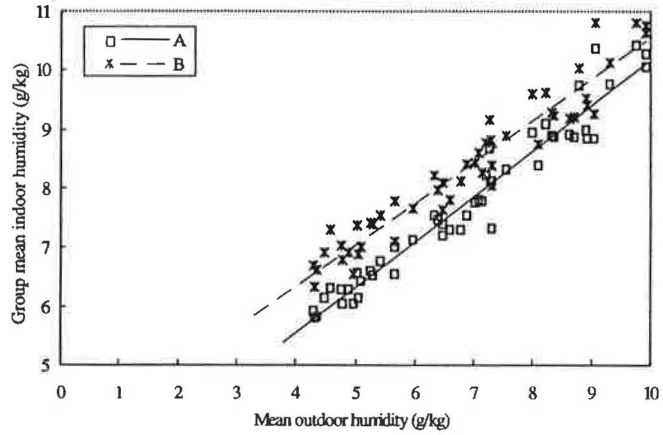

Figure 4 Weekly group mean bedroom absolute humidity over period P2. Linear regression of bedroom humidity g on outdoor humidity g_o was carried out to give best fit line $g = a + bg_o$. (See Table 4.)

Table 4 Results of regression analysis of bedroom humidity on outdoor humidity

Group	*a*	*b*	r^2
A	2.47	0.77	0.95
B	3.55	0.70	0.93

for the entire post-intervention period P2. The points are well fitted by linear regression. The mechanically ventilated houses have a lower bedroom humidity than the non-mechanically ventilated houses over the whole season, both winter and summer. The difference is greater in winter, being 0.73 g kg^{-1} at an outdoor humidity of 5 g kg^{-1}, and 0.38 g kg^{-1} at an outdoor humidity of 10 g kg^{-1}. Figure 5 shows an alternative way of showing the difference between groups, where the houses are classified by mean winter indoor humidity. The mean winter indoor humidity is below the WHO level in 75% of Group A, as compared with only 15% of Group B.

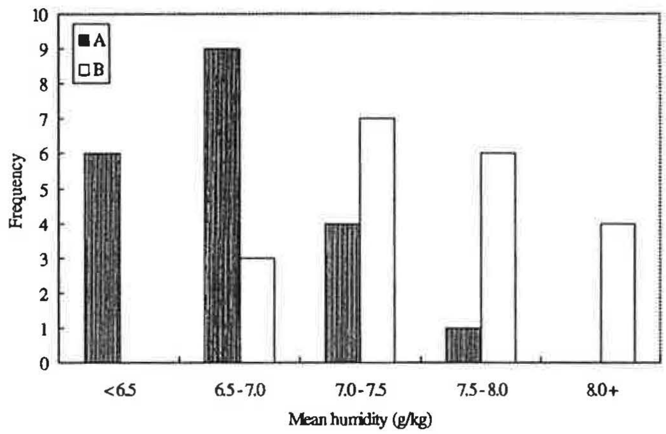

Figure 5 Distribution of the mean bedroom absolute humidity measured over the winter period P3. Of the 20 houses in each group, the proportions of individual house mean humidities below 7g kg^{-1} were 15/20 for Group A and 3/20 for Group B.

Data logging started some weeks before the mechanical ventilation systems were installed and turned on. It is therefore possible to compare humidities within houses before and after the intervention. To compare like with like, the comparison was made between periods P1 and P5, i.e. the same period (weeks 27 to 43) in successive years. Separate linear regressions were carried out of indoor humidity g versus outdoor humidity g_o. Houses in Group B showed no change year on year, whereas those in Group A showed a significantly lower humidity in 1995 compared with the same period in 1994, before the system was turned on ($P < 0.05$). The average

Table 3 Distribution of weekly mean values for all houses, separately by groups

Group		Period	*n*	Lower quartile	Median	Upper quartile
A	Temperature (°C)	P2	1005	17.80	19.36	21.26
		P3	359	16.51	17.75	18.59
		P4	160	22.46	23.47	24.52
	Moisture content (g kg^{-1})	P2	1005	6.61	7.65	8.88
		P3	359	6.11	6.69	7.29
		P4	160	8.75	9.35	10.46
B	Temperature (°C)	P2	1006	17.25	18.91	20.99
		P3	354	16.05	17.26	18.40
		P4	160	22.03	23.16	24.03
	Moisture content (g kg^{-1})	P2	1006	7.26	8.31	9.39
		P3	354	6.77	7.43	8.15
		P4	160	9.17	9.92	10.69

reduction in humidity is about 0.5 g kg^{-1}, somewhat smaller than the difference observed between the groups of houses.

3.3 House air leakage rate

The air tightness of the experimental houses was measured by BRE using a standard fan pressurisation test[14]. Of the 40 houses in the survey, leakage data are available for 35. The median leakiness, expressed as the number of air changes per hour at a pressure difference of 50 Pa, was L_{50} = 16.6 ac h^{-1}. This is a relatively high figure, being above the median L_{50} of 13 ac h^{-1} for UK building stock[15]. The distribution of house leakage for 35 houses is shown in Figure 6. House leakage is expressed as Q_{50}, the air leakage flow rate in m^3 per hour at 50 Pa pressure difference.

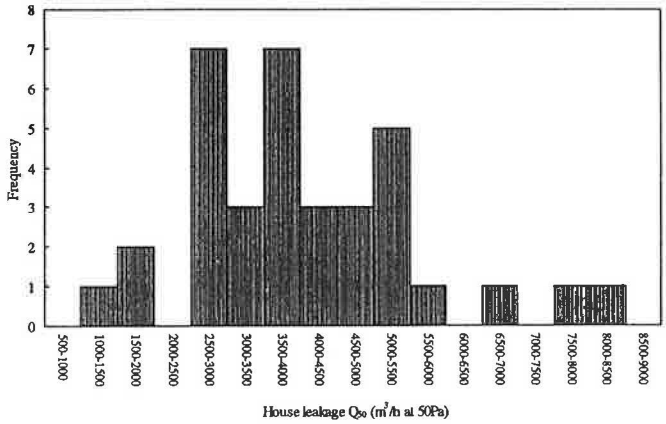

Figure 6 Histogram of house leakage for 35 houses

The question remains as to whether the air leakage rate affected indoor humidity, therefore the effect of house leakiness was explored. Linear regression was used, with inside–outside humidity difference as the dependent variable and leakage Q_{50} as the independent variable. Separate regression lines were fitted for Group A and B and displayed as Figures 7 and 8 respectively. Each point represents the mean value for one house averaged over the 18 weeks of period P3. Figure 8 includes two outlying points, one of which relates to a house with seven occupants and a much higher humidity than all the other houses. Removing the outlying points did not change the conclusions of the analysis. Houses in Group A show a significant effect of leakiness, with leaky houses showing lower humidity. In Group B the humidity was not affected by the house leakiness.

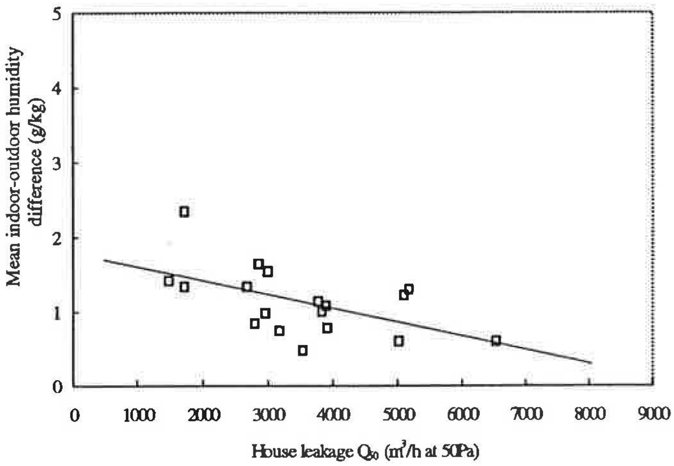

Figure 7 Effect of house air leakage rate on humidity for Group A in winter period P3 (See Table 5.)

Table 5 Results of regression analysis of house air leakage rate on indoor–outdoor humidity difference for Group A

Group	*a*	*b*	r^2
A	1.78	–0.00019	0.30

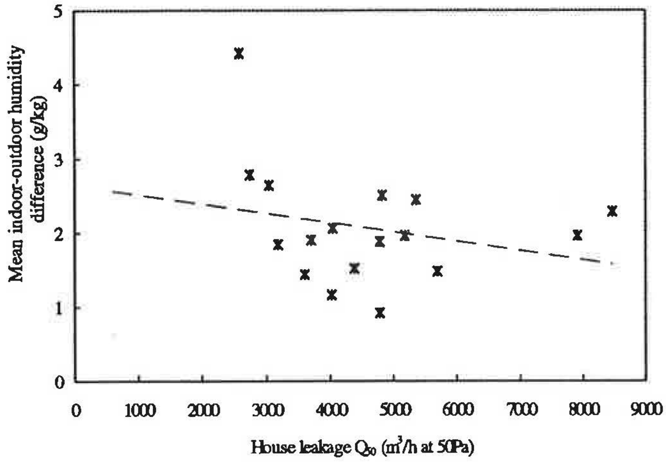

Figure 8 Effect of house air leakage rate on humidity for Group B in winter period P3. (See Table 6.) Removal of two outlying points does not alter significance.

Table 6 Results of regression analysis of house air leakage rate on indoor–outdoor humidity difference for Group B

Group	*a*	*b*	r^2
B	2.64	–0.00012	0.06

3.4 User reaction

Householders in Group A were asked to complete a questionnaire about their experience of the ventilation system. The questionnaire was designed to obtain a picture of the user's reactions. Results were not tested statistically. The questionnaires were distributed at the end of summer 1995, i.e. when the householders had nearly a year's experience of the system. The preamble to the questionnaire referred specifically to the winter period. All 20 householders returned the questionnaires. The results are summarised in Table 7. Results were generally favourable. Noise in bedrooms was not a problem. Three households reported that draughts in bedrooms were enough to be disliked. Seven of the households reported that they did on occasion open a bedroom window during winter, though the questionnaire did not ask about the frequency of opening. The responses to the open questions revealed more specific problems. There were several positive responses to air quality, freshness and reduction in condensation. Four respondents found that the bathroom extract was noisy during boost operation. Two considered that bedrooms were now colder and three complained about dusty rings round the air supply inlets in the bedroom ceilings. There were some comments on the standard of installation.

4 Discussion

4.1 Temperature

The temperature behaviour was typical of dwellings, implying that little heating is used when the outdoor temperature is above 15°C. Below this, heating is widely used to maintain

Table 7 Results from questionnaire issued to houses in Group A

Question	Response options	Frequency
Did you find the system made any noise in the bedrooms?	Often disturbed sleep	0
	Could be heard and was annoying	0
	Could be heard, but was no problem	6
	Could not normally be heard	12
For the trial, you have been asked not to open bedroom windows. Over the winter, would you say you:	Never needed to open a bedroom window	8
	Sometimes wished you could	2
	Often would have liked to open a window	0
	Actually sometimes did open a window	7
Did you feel that the air inlets produced any draughts in the bedrooms?	Did not notice any draughts	13
	Could be felt, but not a problem	2
	Produced discomfort occasionally	2
	Often produced uncomfortable draughts	1
In cold weather, did you experience condensation on bedroom windows?	Severe: enough to make pools of water	1
	Moderate: windows need wiping	3
	Slight: occasional mist	3
	None	7
Over the winter, would you say that the ventilation system made the bedrooms	Warmer than usual	2
	No effect	10
	Cooler than usual	6
Over the winter, would you say that the ventilation system made the air in the bedrooms	Fresher than usual	14
	No effect	4
	Stuffier than usual	0

comfort. The fall in mean indoor temperature with reducing outdoor temperature below 15°C reflects the effect of intermittent heating and occasional absences, as well as a willingness to accept lower indoor temperatures during colder weather.

4.2 Humidity

Group A houses had significantly lower humidities than those in Group B and a substantially larger proportion had a mean winter humidity below the WHO recommendation of 7 g kg^{-1}. The experiment took place on the south coast of the UK during an exceptionally mild and humid winter. We can reasonably expect that indoor humidities would be lower in more typical years. Indoor absolute humidities would also tend to be affected more by mechanical ventilation in colder, less humid regions, because of the lower moisture content of the air supplied. It is noted that, assuming a lower outdoor absolute humidity, ventilation alone (without dehumidification, e.g. moisture removal) can only ever reduce the absolute humidity to the level of the outdoor air. In steady-state conditions, the indoor absolute humidity is equal to the outdoor humidity plus a term proportional to the rate of indoor moisture production divided by the ventilation rate. Figure 3 shows that indoor humidity is influenced directly by that outdoors over the whole period. Throughout the winter, Group A has a lower mean humidity than Group B, in accordance with the expected effect of mechanical ventilation.

The WHO level is supported by several surveys, but more information is needed to support the use of ventilation and humidity control to reduce house dust mites. Information is needed on the duration of low humidity required to produce a worthwhile reduction in mite numbers, together with information on the effects of excursions of humidity above the level. The microclimate that the mites inhabit in carpet or mattress is different from that measured in free air. It is possible that humidity control will need to be reinforced by other measures.

4.3 House air leakage rate

Mechanical ventilation with heat recovery was developed and introduced primarily to achieve good ventilation associated with low running costs in well insulated and airtight dwellings. The value of the heat recovered in the heat exchanger will normally exceed the running costs associated with the fans. Further reductions in running cost compared with natural ventilation arise from the improved efficiency of the system, in that stale air is extracted at source and the incoming fresh air directed into the inhabited rooms. In this way, satisfactory ventilation may be achieved with a lower overall ventilation rate than that of a natural ventilation system. A mechanical ventilation system is normally balanced with equal supply and extraction rates, or with slight excess of extract over supply. A leaky house envelope contributes to the overall ventilation rate. The effect of leakage could confound the effects attributed to mechanical ventilation. Accordingly, the data were analysed to check whether the leakiness was distributed evenly between Group A and Group B. The skewed distribution of the leakage results led to the adoption of non-parametric statistics for the analysis. The Kruskal–Wallis H test showed no significant difference between groups for leakiness. The mechanical flows add to any adventitious ventilation occurring through leakage in the building fabric. It is therefore, recommended that MVHR systems be installed in houses with a high standard of air tightness.

Figures 7 and 8 show that houses in Group A have lower humidities than Group B, where house leakiness appears to have little or no effect on the level of bedroom humidity.

The mechanical ventilation system was set to supply fresh air to the bedrooms at a supply rate that is conventional for MVHR systems. However, in this case there was no continuous ventilation downstairs, resulting in a potentially lower overall ventilation rate for the whole house. The provision of controlled ventilation in a house with a high standard of air tightness allows the optimum balance between humidity control and energy conservation.

4.4 Ventilation system

Houses were chosen for the trial according to the availability of volunteers from the Southampton asthma clinics. The available houses showed a wide range of age and construction. The choice of an upstairs-only MVHR system coupled with kitchen extract fan proved successful, allowing installation with minimum disruption. Even so, there were comments from some householders that the system took up space in the loft. So far, maintenance has been carried out by the original contractors. Changing the filter and cleaning the heat exchanger involve removing external insulation from the mechanical unit and re-insulating afterwards. This is not satisfactory and may inhibit maintenance by householders. The system appears to have been little disliked in use, with some very positive comments. All comments relating to the ventilation systems have been passed on to the system manufacturers.

5 Conclusions

The use of mechanical ventilation systems reduced the measured bedroom humidities in a sample of 20 houses, compared with a group of 20 houses without mechanical ventilation. The mean reduction in mixing ratio measured over the four winter months was 0.75 g kg^{-1}. The effect that this would have on dust mite populations is not reliably predictable but, in due course, empirical data will be available from this study.

15 of the 20 houses with MVHR had a mean bedroom humidity below the WHO level for mite control of 7 g kg^{-1} over the winter months, compared with three out of 20 control houses. The use of upstairs-only MVHR systems, coupled with kitchen extract ventilation, facilitated installation and proved satisfactory in operation. Householder reaction was generally favourable. It appears that house leakiness adds to the humidity reducing effect of MVHR. Where ventilation is critical, it may be necessary to adjust the rate of mechanical ventilation to match the house characteristics.

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This report describes only part of a larger study and would not have been possible without the collaboration of all other parties involved.

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