Multiple Occupancy Residential Accommodation-Ensuring Good Indoor Environments.

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Abstract

Multiple occupancy residential accommodation has become an increasingly popular building typology in the UK. Purpose built residential units with individual bedrooms and en-suite bathrooms are particularly common to student halls of residences, care homes and hostels. These building types are similar in that residents intensively occupy their bedroom as a living space- this intensity of occupation makes the provision of good indoor environment and air quality of paramount importance to resident's health and wellbeing. This paper seeks to highlight issues which are likely to be prevalent in this building typology by using a student hall of residence as a case study. These potential issues are partly due to the habits of the user but also issues related to the on-going maintenance of the building to ensure adequate ventilation and good air quality. This paper concludes by suggesting a methodology which housing providers could use to determine the potential causes of poor indoor air quality thereby improving the health and well-being of occupant.

Keywords- air quality, ventilation, health and well being.

Context

Similar to many UK cities, Glasgow has seen a large number of student residential buildings being constructed over the last 10-15 years to satisfy the demand for budget accommodation for students. Privately owned providers of student accommodation in the UK have significantly increased their residential stock to respond to the growth in the International student market at UK universities. This has also been partly in response to further education institutions reluctance to develop their own estates, preferring to outsource the provision to private accommodation providers.

Spatially most student accommodation units have shared bedroom/ living spaces which are frequently volumetrically very small- both in floor area and ceiling height. Constructed by profit driven private accommodation providers maximising number of units per development leads to the creation of very tight floor plans- the average room size in a new built student hall is $11m^2$ including the en-suite bathroom. En-suite bathrooms are the norm and to ensure space efficiency these are often designed to be internal without windows but relying solely on mechanical ventilation for extract. The importance of the performance of the mechanical extract then becomes critical in the removal of moisture and dampness in the bathroom which may form mould growth on bathroom surfaces. As the bathrooms are directly connected to the bedroom/living space then any excess moisture is subject to migration into the bedroom creating a damp indoor environment and possible mould growth on surfaces within the living space. The use of trickle vents and window opening is user dependant and if there is the potential for cold draughts and associated heat loss then data indicates users' reluctance to ventilate living spaces. A poorly ventilated living space will be subject to high levels of $C0_2$ which can lead to drowsiness, headaches and a lack of general well-being.
Recent research undertaken by the Mackintosh Environmental Architecture Research Unit (MEARU) indicates that even in new built homes many recently installed mechanical ventilation systems failed to meet the required air flow extract rate required to effectively remove moisture from homes (Sharpe T et al, 2014).

All these factors see multiple occupancy residential units having increasing importance in our built environment and this paper takes a case study project to review indoor environmental conditions and

gain qualitative data from their users. MEARU undertook a project in March 2013 to review the indoor air quality of a student housing block in Glasgow City centre constructed in 1995. The development was purpose built as student halls of residence to house up to 115 students. There are a total of 18 flats with a mix of en-suite and shared bathrooms. This particular development sits within a traditional tenemental layout and therefore was restricted in height to 4/5 storeys however most new student developments within Glasgow are higher to maximise the density and intensity of occupation. The room sizes are very compact- 9m2 in most situations with bathrooms of 2m2. Floor to ceiling heights are standard of new build residential developments (2.4 m). In keeping with the neighbouring tenements the development has quite large windows relative to floor area. In these restricted volumes (approx. room size 23m3), ventilation and air quality are particularly relevant.
The accommodation management had experienced numerous complaints of mould and dampness within certain flats- although not all of them.

This paper seeks to highlight common air quality issues prevalent in this building typology, which are often attributed to the habits of the user but which are often due to inadequate maintenance of the building and its mechanical equipment (which are critical to ensuring adequate ventilation and good air quality). Recent research suggests that the drive for energy efficient air tight homes is not necessarily creating healthy indoor environments due to the poor indoor air quality often recorded in these homes (Crump D, 2009). This paper highlights that due to current increasing demand for airtight homes which rely on mechanical forms of air supply and extract, problems with these ventilation systems significantly impact the indoor air quality and thereby the health and well being of occupants.

Methodology

The survey work was undertaken in 3 distinct stages to identify both quantitative and qualitative data:

Survey Investigation, Stage 1. Initially a site visit to 3 typical flats which had recurring issues with dampness, condensation and high electricity costs was undertaken. After discussions with the residential manager to identify repeated problems and recurring complaints, 3 flats (each with 6 rooms) were selected for in-depth monitoring. These ones had received most complaints over recent years and some rooms were considered ‘problems’ - although many of the issues identified are typical of those experienced across the other flats to a lesser degree.
Background research into the construction typology and flat type layouts of the residential halls was then undertaken. An investigative questionnaire was distributed to the residents of the flats which were selected for monitoring. The questionnaire aimed to identify if there were any resident habits which may be affecting the environmental condition of their bedroom. Residents were asked how often they open windows; adjust trickle vents and questions regarding their heating regime and expenditure on energy per week were also included. Of the 18 questionnaires issued, 10 were returned fully completed. The residents had all been living in the accommodation for at least 9 months so their responses reflect their experiences from the months from September 2013- May 2014.

Survey Investigation, Stage 2. Monitoring equipment was installed in the 3 flats which had been identified as suitable during initial site visit. Bedrooms and shared kitchens were monitored over a 2 week period in each flat (between February and April 2013). The equipment monitored CO_2, Relative Humidity and Temperature which all helped to assess the indoor quality within the flats. (Eltek RX250AL receiver (Squirrel) loggers. GD47 transmitters with sensors built in for RH, temperature and CO_2 (0-5000ppm were used). The results of the monitoring data were analysed using Excel to identify and explain patterns and peaks. During the monitoring period, students were also invited to keep a diary of occupancy patterns and habits over the 2 weeks which were compared with the measured data to gather more qualitative data regarding their heating use, ventilation awareness and other key air quality markers. A visual survey was undertaken across a selection of flats which had recurring issues with moisture and evidence of mould and dampness was documented. Several flats exhibited excessively high moisture readings combined with persistent mould and general damp odour in bathroom spaces.

Detailed Survey Investigation, Stage 3. In each of the monitored flats, the bathroom extract fans were then tested using an automatic volume flow meter with pressure compensation (and light extension hood). Each of the airflow reading were recorded and compared against current building standards for recommended air extract rates. A further stage of investigation work to the fans and ductwork was undertaken by an electrical contractor and the fan unit, grilles and ductwork was thoroughly cleaned-the flexi duct to the grille was replaced in several locations. Testing to ascertain improvements were undertaken again with the air flow meter. Fan units which were still giving ineffective readings were then further inspected using an endoscope to identify possible damage or blockages in the ductwork. Ultimately panels within the bathroom required to be removed in order to access the main duct riser and check for any blockages. Final flow rate testing was then completed using the automatic volume flow meter.

Survey findings

Stage 1- Visual Observations + Resident Questionnaire responses- 12 rooms monitored in 3 different flats

The interview and site visit with Residential Accommodation Manager was held in January 2013 and this included a site visit to typical flats which had recurring issues with dampness, condensation and high electricity costs. Discussions with the manager and resident warden were a most informative part of this study as both having been dealing with student resident requests and complaints for many years. Questionnaires were distributed to students in the flats which were monitored to gain feedback regarding heating and ventilation habits and whether they experienced dampness or mould within their room.

Heating

When asked about the ease of operation of the heaters in the bedrooms in the resident survey questionnaire, 70% of students noted that the heaters were simple to operate however opinions were evenly divided regarding their effectiveness in heating the room. The recurring criticism was the inability to keep an even temperature in the room at night. Each flat has a pre-paid electricity meter, which charges for the total electricity used in the flat (including the power used in each student's room). When asked about the cost of heating room to a comfortable level and affordability, 90% of students noted it was 'very expensive'. Residents were asked to make an estimation of weekly expenditure on energy cost (electricity) per person within the flat. 50% noted between £6-10 per week with 30% estimating between £11-20. The others admitted that they had no idea how much it was but found it prohibitively costly. Some students noted that this figure may be lower than £5 outwith winter months but most had only been resident for 9 months from Sept/Oct during the heating season. Given the high costs of heating their living space students noted reluctance in ventilating their bedrooms in order to retain heat.

Ventilation

Extract fans (activated with light switch) in the en-suite bathrooms are on a timer with a 10 minute run-on period. Bathroom doors on shared bathrooms have metal door ventilation grilles and the doors themselves have self-closing devices (although not all these are functional). The ducted extract fans run up the central core of the building and outlet is at roof level. Students are also requested not to shower with bathroom doors open as this may trigger smoke alarms. Defective self-closing devices on en-suite doors let moisture migrate into the bedroom so the importance of an effective ventilation system in the bathrooms is paramount. On initial visual inspection it was evident that the grilles needed to be cleaned on a regular basis to ensure optimal performance (Image 1).

	
Extract fan in Common kitchen/lounge area	Extract fan in bathrooms (both en-suite and shared)

Image 1. Extract fan grilles in a typical flat.

90% of residents noted that the extract fans in the bathrooms were not effective at removing steam from their room and resort to opening windows to remove excess moisture. One resident commented that this was problematic due to the security risk of leaving windows open when the room is vacant. Students are discouraged from opening windows on ground floor when room is not occupied due to security risks. It was noticeable that the flats on the ground floor experienced greater dampness problems - this could be attributed to less frequent window opening.
There are trickle vents on each bedroom window however, these are difficult to access as they are located on the window head approx. 2m off above floor level and many are concealed by net curtains. Some students have positioned their desk in front of the window therefore making access to trickle vent more problematic. The survey indicated that only 20% regularly adjusted the trickle vents for ventilation with 60% having them predominantly closed.

Mould and dampness
Several flats visited were stuffy and had a strong smell of dampness and mould. Mould was visible in all of the bathrooms (both shared and en-suite). The shower surrounds themselves were free from mould given the PVC easy clean panels but mould was very evident on painted ceiling and adjacent wall surfaces. In addition, mould was present on every bathroom door due to the hanging of damp towels on a timber veneered door without a heat source or sufficient level of ventilation. In addition there was evidence of mould which had been painted over rather than washed down and removed prior to re-decoration (Image 2). Mould was also visible around most window frames- this is most likely due to surface condensation running down the window and gathering on the sill and net curtain.

Mould on painted surfaces in bathrooms	Mould growth spores above WC

Image 2.Evidence of mould growth on painted surfaces within the bathrooms.

Mould was also evident in the corners of rooms and behind furniture/ beds. These are areas which do not get any air movement and due to the restricted size of the rooms and the requirement for desk and storage, the capacity for air movement within rooms is very limited. During Christmas and Easter breaks the students will often be away and the accommodation is left uninhabited and unheated for up to 3 weeks during the coldest months of the year. Periods of un-occupancy without heating will cause the surface temperatures to drop leading to the formation of dampness and mould on cold spots of the building fabric.

90% of students have observed condensation in their room predominantly on windows after showering. 90% of students have observed mould growth on the walls and surfaces within their flat- 60% noted mould within their bathrooms. 40% have mould growth on the walls and surfaces in their bedroom.

Students are encouraged to keep bathroom doors closed	Students on ground floor are encouraged to keep windows closed whilst room unoccupied

Image 3. Advisory notes to occupiers from the property managers

Students are forbidden to dry clothes over the convector radiators due to fire risks however there is no heated towel rail to dry damp towels in bathrooms and during visual inspection it was evident that all rooms had damp towels draping over doors and/or furniture (Image 4).

	
Towel draped over bathroom door	Mould growth due to damp towel hanging on bathroom door

Image 4. In adequate provision for drying damp towels.

The use of the communal laundry is encouraged to prevent students from clothes washing and drying within bedrooms and this facility appears to be well used but has a cost penalty and there was evidence of ad hoc drying in bathrooms and bedrooms. The questionnaire responses highlight a trend of washing clothes but failing to tumble dry all clothes due to prohibitive costs of a drying cycle.
90% of students use the communal laundry on a regular basis doing 2-3 loads on a monthly basis. However 80% of respondents admitted to ad hoc drying of towels, clothes or bedding within their bedroom either over the bathroom door, furniture or on a clothes airer. 30% (of those 80%) would keep their heating on (or increase the temperature) in the presence of wet clothes.

In addition to the qualitative data, further investigations using monitoring equipment to assess the environmental conditions which students had been mentioning in their survey interviews.

Stage 2- Monitored Data
Results and Analysis- Environmental Monitoring

Monitoring equipment was installed in the bedrooms of 3 flats over a 2 week period during the heating session.

The 3 flats were different in their location within the block- Two were on the Ground floor (one with shared bathrooms on an East /West axis and one with en-suites with North/ South axis). The other flat was on an upper floor on the North/South orientation. The equipment monitored CO_2, Relative Humidity and Temperature which all helped to assess the indoor quality within the flats. The results of the monitoring data were analysed using Excel to identify and explain patterns and peaks.

Flat CG, 4 person Ground floor flat with shared bathrooms
All 3 monitored flats on the West elevation
26 February 20013 – 12 March 2013 (3 bedrooms monitored)

	Orientation	Temp (°C) Mean	Temp (°C)min	Temp(°C) max	CO^2 (ppm) Mean	CO^2 (ppm) min	CO^2(ppm) max	RH-% Mean	RH-% min	RH-% max
Room 1	West	18.7	9	23	2174.5	475	4741	62.5	31	74
Room 2	West	17.6	15	23	1108	407	3777	53.7	32	72
Room 3	West	16.3	12.4	22.9	1842	631	4890	62.5	30	75.7

Figure 1. Monitored data results (FlatCG).

As these flats do not have en-suite bathrooms, the bedrooms should not be subject to migrating moisture from showers therefore the high moisture levels must be attributed to insufficient ventilation with high moisture levels possibly exacerbated by hair drying and drying clothes/towels.
CO_2 levels are very high suggesting that windows are not being opened on a regular basis. As all the rooms were in the West Facing elevation this is perhaps due to the security risk from being at pavement level. The West façade will also take the brunt of driving wind and rain which may also discourage window opening.

Flat AG, 5 person ground floor flat, en-suite
North/South orientation. East elevation adjoins existing tenement construction.
West elevation forms pend entrance to courtyard
31 March 2013 – 14 April 2013

	Orientation	Temp (°C) Mean	Temp (°C)min	Temp(°C) max	CO^2 (ppm) Mean	CO^2 (ppm) min	CO^2(ppm) max	RH-% Mean	RH-% min	RH-% max
Flat 2	North	19.9	16.9	23.9	2443	528	4857	72.6	37.1	87.2
Flat 3	North	21.6	16.5	21.1	1231	493	3129	59.5	38.3	84.9
Flat 4	South	21.8	18.2	22.5	1405	433	4421	56.0	33.8	85.6
Flat 5	South	20.6	18.0	25.9	1454	401	3222	64.7	37	81.0
Common room	South	18.7	17.0	24.8	953	457	2705	62.4	35.2	90.1

Figure 2. Monitored data results (Flat AG).

CO_2 levels in all bedrooms in flat AG are at very high levels. This suggests that windows are not being opened on a regular basis - perhaps due to the security risk from being on the ground floor.

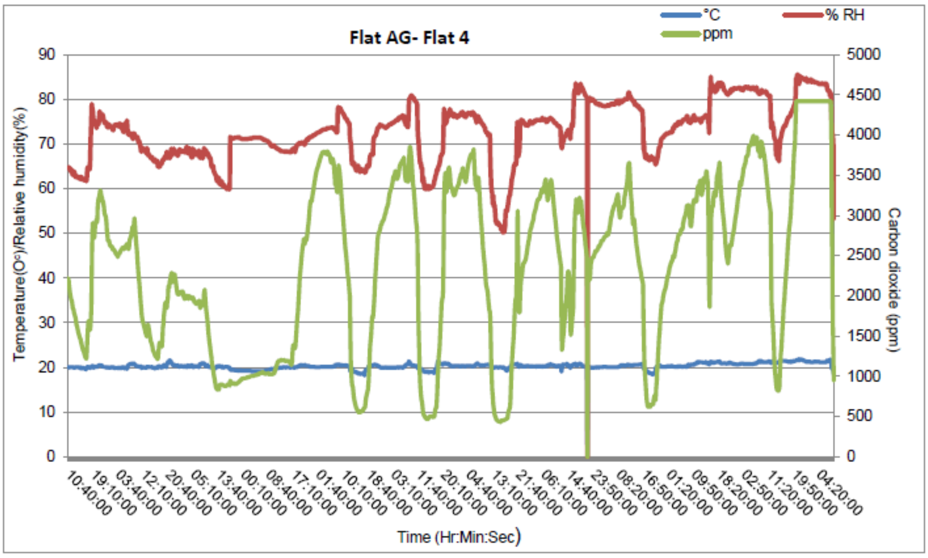

Figure 3. Graphical data results (Flat AG).

Average humidity levels are high however a key concern are the maximum levels of 87% in bedrooms- this indicates that steam must certainly be migrating from the shower room. These high levels also highlight that an effective fan is critical to remove the moisture.

Flat A1, 6 person first floor flat, en-suite
14 April 2013– 28 April 2013

	Orientation	Temp (°C) Mean	Temp (°C)min	Temp(°C) max	CO^2 (ppm) Mean	CO^2 (ppm) min	CO^2(ppm) max	RH-% Mean	RH-% min	RH-% max
Flat 1	North	19.0	17.0	23.9	1165	528	3399	59.0	37.1	73.2
Flat 2	North	19.3	16.5	20.4	1286	462	2343	59.3	42.3	70
Flat 3	North	20.3	18.2	21.9	2397	433	4421	72.8	50.2	85.6
Flat 4	South	19.7	18.2	21.8	898	479	3222	65.9	48.4	81
Flat 5	South	20.26	17.0	23.0	989	457	2855	48.1	35.2	63.8

Figure 4. Monitored data results (flatA1).

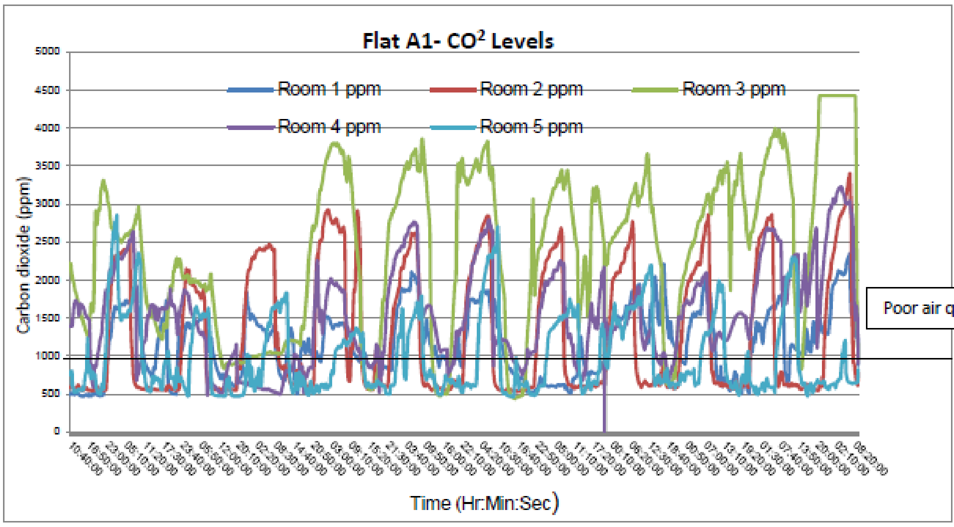

Figure 5. Graphical data results (FlatA1).

Again average CO_2 levels are at very high levels in all rooms in this flat suggesting that there is insufficient fresh air entering the flat- despite survey responses indicating that windows are opened frequently. The black line indicates the value of 1000 ppm- this is the tolerable indoor air quality and above this level tiredness and lack of concentration can occur.

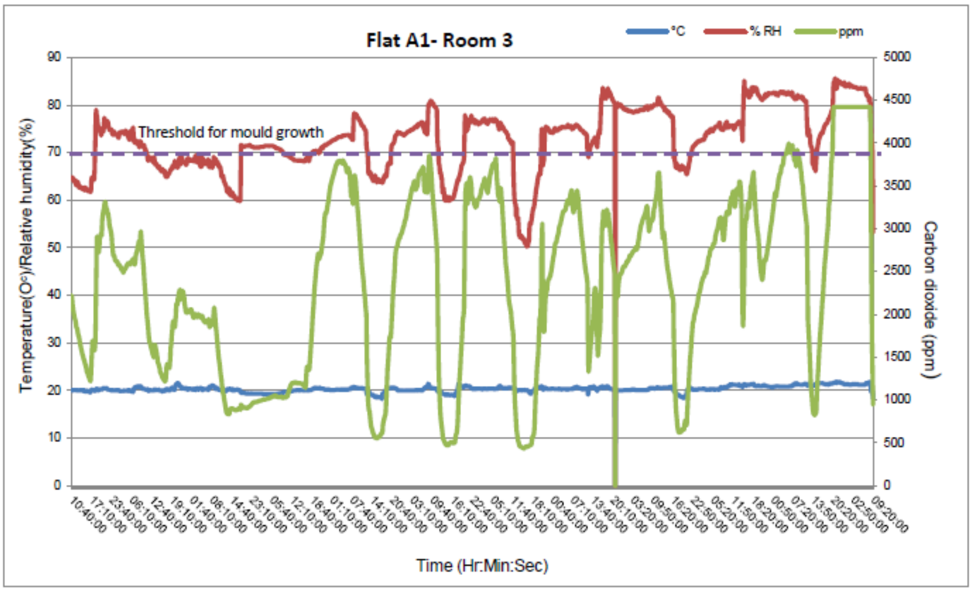

Figure 6. Threshold for mould growth(flatA1, room 3).

Room 3 (as above) has both extremely high CO_2 levels and spikes in RH levels. These reading are consistent with mould observed within both the bedroom and bathroom. The dotted line indicates the 70% RH threshold for mould growth. These high levels of humidity can cause both mould growth and dust mites both of which can trigger respiratory illness in susceptible individuals. To further investigate these results a fan test was undertaken to determine the efficiency of the bathroom extract fan. The reading of 2.4l/s as opposed to the required 15l/s was recorded which explains the excess moisture in the air.

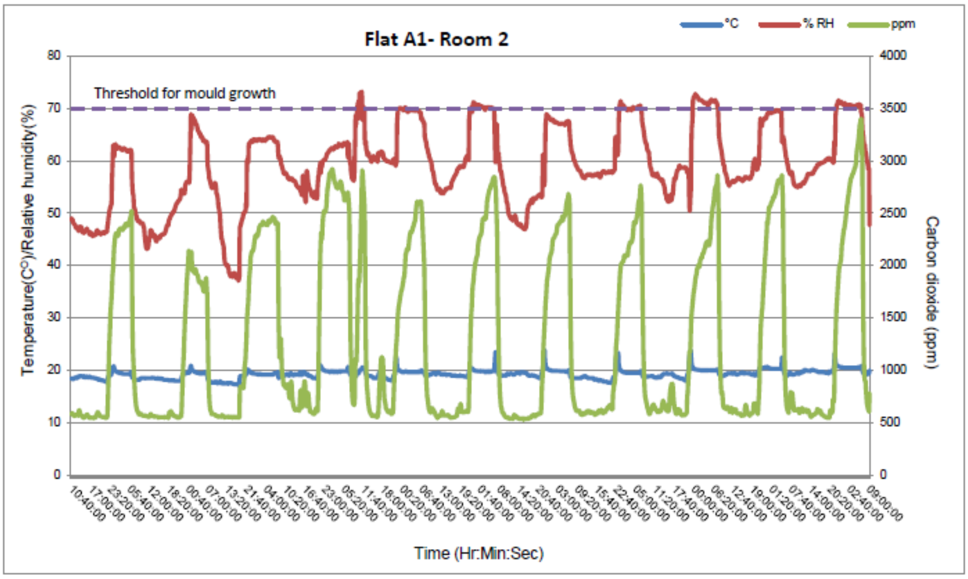

Figure 7. Threshold for mould growth(FlatA1, room 2).

Detailed Survey Investigation, Stage 3.
Fan testing of poorly performing extracts in bathrooms.

The objective of the testing was to ascertain whether the performance of the extract fans, located in bathrooms in each flat are operating in compliance with the Building (Scotland) Regulations. The building regulations under which the residences were built stipulated that extract fans in bathrooms must meet 15l/s (Part K 1990).
Volume flow rates were measured using the following instruments:

Observator Instruments	Automatic volume flow meter with pressure compensation
Type:	Diff Automatic
Cert No:	UK08111MN
Calibrated:	20th June 2013
Observator Instruments	Light extension hood
Type:	AT-242
Cert No:	UK08111MN
Calibrated:	20th June 2013

Figure 8. Specification of equipment used to undertake fan testing.

The equipment was operated as per the manufacturer's instructions. Fans were switched to operate and three volume flow measurements were taken at each fan inlet (in litres per second), once the air flow had stabilised. The final result of the testing was an average of the three measurements taken.

Extract Fan Location	Fan Operation	Method of start	Fan Run on
En-suite Bathroom	Intermittent	Light Switch	10 minutes

Extract Fan Location	Fan Operation	Method of start	Fan Run on
Shared Bathroom	Intermittent	Light Switch	10 minutes

Figure 9. Specification of extract fans and their location.

Dwelling	Fan Location	Manufacturer	Average Measured extract rate (l/s)	Design extract rate (l/s)	Pass/Fail Measurement test
AG					
Room 2	Bathroom	Nuaire	10.4	15	Fail
Room 3	Bathroom	Nuaire	9	15	Fail
Room 4	Bathroom	Nuaire	6.5	15	Fail
Room 5	Bathroom	Nuaire	0.0	15	Fail
A1					
Room 1	Bathroom	Nuaire	8.2	15	Fail
Room 2	Bathroom	Nuaire	2.9	15	Fail
Room 3	Bathroom	Nuaire	2.4	15	Fail
Room 4	Bathroom	Nuaire	12.6	15	Fail
Room 5	Bathroom	Nuaire	8.5	15	Fail
CG					
Communal Bathroom 1	Bathroom	Nuaire	3.2	15	Fail
Communal Bathroom 2	Bathroom	Nuaire	4.9	15	Fail

Air Flow Measurement of Extract Fans against Design Flow Rates.

Figure 10. Test data of recorded air flow of bathroom extract fans.

The need for extract ventilation is to ensure that excess water vapour produced in sufficient quantities is extracted quickly and effectively at source, e.g. from bathing and cooking activities. This is to reduce the risk of creating conditions that are able to support germination and growth of mould, harmful bacteria, pathogens and allergies. The testing was undertaken in 3 flats in this study to determine whether the installed systems had the required capacity to meet Building (Scotland) Regulations.

Average of air flow through all fans tested was 6.86 l/s (as opposed to required 15l/s) which is 45% of the efficiency of that required by Building (Scotland) Regulations. The fan with the lowest flow was only working at 16% effectiveness and of those measured there was one fan not working at all.
It is evident from the testing undertaken that deficiencies exist with the current ventilation system-. Frequent under-performance of mechanical extraction units is most likely a major cause of the excess moisture and mould growth within the flats and this required further investigation to identify causes of the defective extract fan system. The bathroom fan units in the problem flats were removed by an electrical contractor and the fan units and grilles were removed and thoroughly cleaned- the flexi duct from the fan unit to the grille was replaced in several locations.

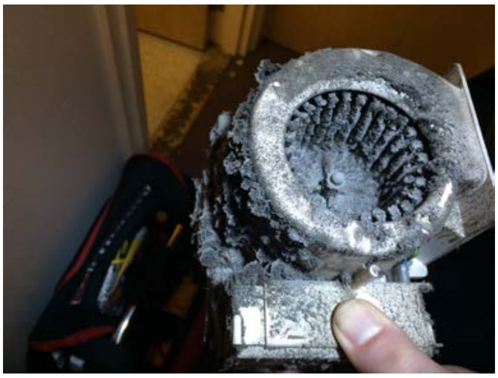	
Excess dust and dirt in fan motor unit	Excess dust and dirt in fan motor unit

Image 5. Fan unit once removed.

Testing to ascertain improvements were undertaken by using the air flow tool which produced unexpected results. In Flat A1, the fan readings were now achieving the required 15l/s rate and one in flat this was now exceeding this. However within the communal bathrooms in CG flat there were no improvements despite the extensive cleaning to the system.

MEARU then further investigated potential blockages or damage to the ductwork by using an endoscope in flat CG (ground floor flat) and the flat above which shares the same duct run. This was the least disruptive method of checking without removing wall panels. The endoscope images identified minor damage to the metal ductwork but its use was limited due to tight radius bends in the ductwork which prohibited the endoscope travelling through the entire duct and into the main chase.

	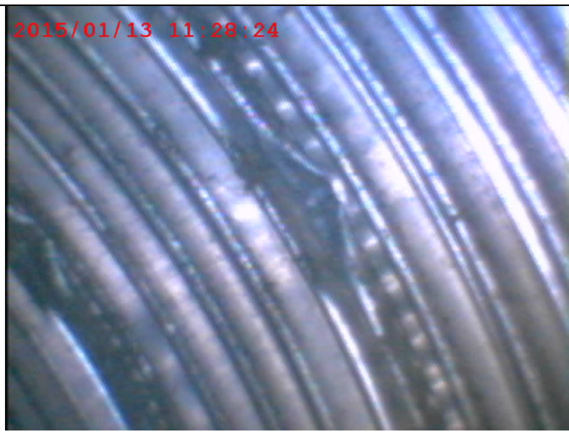
2m length endoscope with handheld camera	Images recorded on endoscope camera showing minor damage to ductwork

Image 6. Using the endoscope and images of ductwork.

Ultimately panels within the bathroom were removed in order to access the main duct chase and check for any blockages. A fire damper which was in the permanently closed position was removed from the duct and which was therefore obstructing airflow from the bathrooms to the air extract at roof level. This fire damper must have been activated into the close position by the buildings fire suppression system and then not been put back into the open position thereby blocking air from extracting through the ventilation system.

Final flow rate testing was then completed in all flats which had bathroom extracts on that ventilation run using the air flow meter. The results indicated that all the extract rates were now meeting the required extract rates.

Fire damper as removed in fixed 'closed' position

Image 7. Fire damper in closed position.

Conclusion

This building performance study has identified potential causes of recurring problems including those of dampness, mould growth and poor air quality. There are high levels of moisture generated from within bedrooms due to inadequate ventilation provision not extracting moisture at source in the shower rooms; hairdryers and clothes drying within the bedroom and this moisture not being dispersed effectively either by underperforming extract fan; resident not opening windows on a regular basis and partly by ineffective trickle vents.

One of biggest moisture problems identified in this study is triggered by the poorly performing extract fans which are not maintained on a regular basis. Those tested had an average performance of 6.86 l/s, well below the required efficiency. The rooms with the highest levels of humidity and CO_2 also had the least effective extract fans. This is leading to significant mould growth within both bathroom and bedrooms. Other exacerbating factors include the very small room size with a limited volume of air to circulate leading to mould formation on walls behind furniture. With an increased reliance of MVHR systems in current new build housing (to reduce energy consumption through airtight construction) the importance of effective mechanical systems to deliver fresh air is critical to creating healthy homes.

In addition to the poorly performing ventilation system there were other problems with the building which makes it difficult for residents to maintain good indoor environment. Moisture and a musty smell caused by the lack of a drying provision for towels. This study highlights that a provision should always be made for drying otherwise mould and mildew will form on the surfaces where the towel is left to drape. Work completed by MEARU's EPSRC funded project titled 'Environmental Impact of Domestic Laundry' (R.Menon and C.Porteous, 2012) identified the potential impact of drying laundry in living spaces and the negative impact on both occupants indoor air quality and associated health issues which residents may experience. The design guide produced as an outcome of that study recommended that all homes should have a designated area which is independently heated and has an effective air extract system.

This paper also identifies through qualitative data that trickle vents are often located in an awkward position in the window- too high up and students are not aware of them. A replacement window system with open able hoppers and well designed trickle vents would significantly improve the supply ventilation to the flats and allow residents to ventilate their living space more effectively. In addition to the use of trickle vents, a number of occupancy habits were identified which may be a contributing factor to the already moist environment evident in the living spaces. Despite the management's efforts and advice, habits are often socio or economic and are therefore very difficult to solve. To ensure that students are aware of the most efficient methods of heating and ventilating their rooms a an occupant guide was produced as an outcome of this study. This guide issued to students when they first move in is included in a student welcome pack and gives advice on heating and ventilation use, trickle vent and window opening and suggests methods of minimising moisture within living spaces. A previous study undertaken by MEARU highlights the effectiveness of occupant guides in reducing energy consumption and assisting occupants in creating healthier indoor environments (Menon R and Sharpe T, 2013). Whilst it is tempting to blame user habits on a poorly performing building, this study identified flaws in the building's ventilation system which created damp spaces in the flats therefore no matter how well the occupant tried to mimise moisture. This study also highlighted that attempts to mask problems through redecoration are often ineffective and ultimately more expensive than addressing the cause of the problem.

Whilst this study was undertaken in student residential accommodation, the problems identified reflect issues relevant in current new build housing in the UK. Floor areas are increasingly restricted with reduced ceiling heights and increasingly airtight construction means that effective ventilation systems must be in place for healthy indoor environments (Wargocki P, 2013). This paper identifies the need for an effective ventilation system to be designed and installed but critically that these area maintained effectively throughout the buildings life to ensure residents have continued healthy and comfortable living spaces.

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