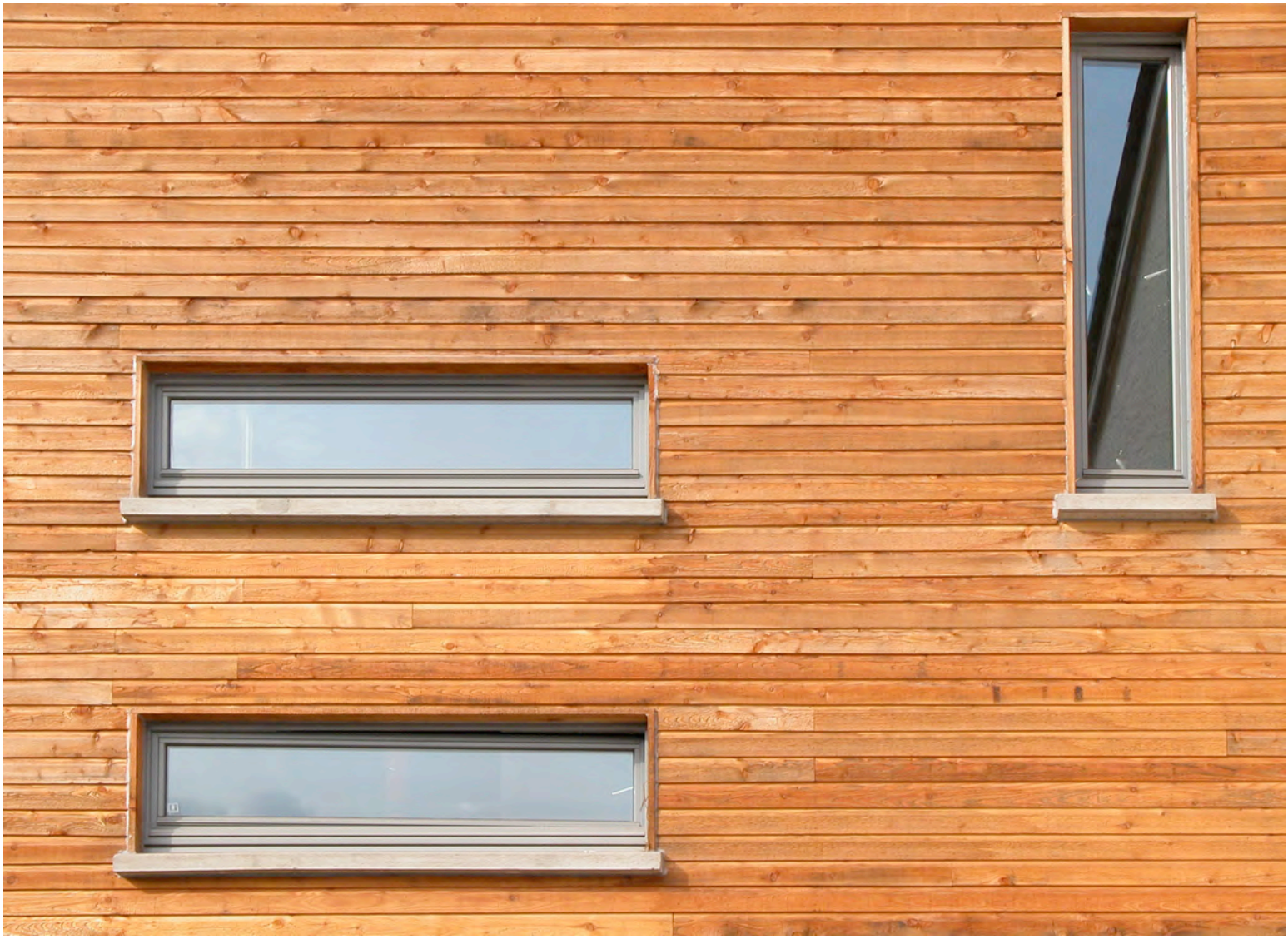
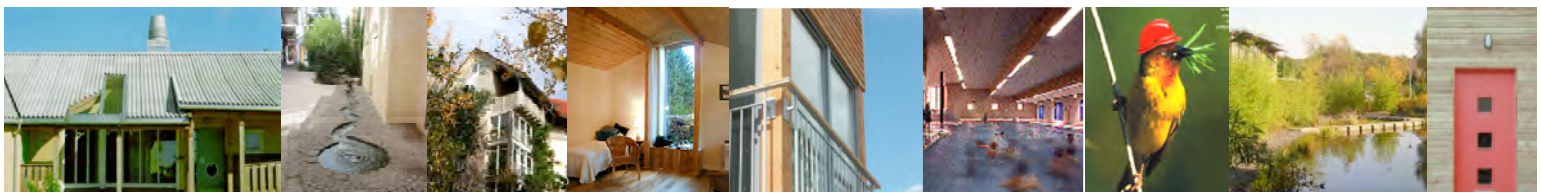


Affordable Low Allergy Housing

A Guidance Note

Gaia Research
and Gaia Architects



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- Gaia Architects are at the forefront of the design of healthy indoor environment and leading proponents of ecological and sustainable built environments. As the architects of Toll House Gardens, they provided both the inspiration and the opportunity to undertake this work, as well as constant support throughout the project. Without them the work would not have been possible.
- Barbara Chapman of Gaia Architects was aided in the early design development by a grant from the RIBA research fund.
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Background

The aim of the project was to develop an affordable low allergy building specification that avoids, where possible, known and suspected building related allergens and minimises the conditions in which they can have an adverse impact. The work is intended to give the same importance in building design to disability through allergy/asthma as is presently the case for physical disability, and to seek appropriate design solutions.

The research is linked to the development of a housing scheme comprising fourteen low allergy, affordable dwellings at Toll House Gardens in Perth, designed by Gaia Architects for a housing co-operative to strict budget guidelines. The scheme is interesting in respect of government sustainable development objectives. It is Phase 10 of a development that has seen a reversal of fortunes from deprivation and crime to a thriving community over a period of two decades. Gaia Architects were responsible for establishing the housing co-operative in 1985 and have subsequently successfully competed for many phases of the work. This has involved both refurbishment and new build with close attention to environmental issues within standard housing cost guidelines. In 2003, the development was one of 5 projects in the world to be honoured with a World Habitat Award. www.bshf.org

The research work was carried out by a team of architects, engineers and cost professionals involved in both research and design practice. The designs were developed with the support of an RIBA research award and the project has also had the in-kind support of a number of interested parties including the architects of the monitored scheme and suppliers of materials and products.

This guidance note is intended to help to deliver replicable, affordable housing that will achieve better quality air and a higher level of health and welfare for allergy sufferers than housing built to minimum standard regulations. The full report on the work is available from Gaia Research. It brings together all relevant information since the inception of the project, including costing of alternative specification and monitored results and includes a review of case studies and demonstration projects.

" good indoor air quality is a human right!"
fin jorgensoen
norwegian engineer

Summary

There is real and increasing concern that housing conditions are a factor in breathing related disability. Issues concerning health effects of buildings are complex, and a wide range of environmental and genetic factors are involved. Consequently, there has been no conclusive evidence on causes and slow progress towards determining appropriate responses. Meanwhile the problems of breathing related disabilities have got notably worse.

More extensive medical based studies would be welcome to clarify opinion. But the extent of breathing related disability in the UK, and the devastating impact it can have on lives, means that it is important that some action is taken. There is arguably a basis for giving the same importance in building design to disability through allergy and asthma as is presently the case for physical disability. Certainly, every effort is needed to minimise sensitisation and reduce the triggers that promote attacks and the conditions that exacerbate them. There is ample evidence to support the development of a precautionary approach to housing design based on best available knowledge. This approach could be modified in the light of information arising in the future. The argument for such an approach is significantly more palatable to many where costs are not excessive.

In support of this, the ODPM have supported research to develop an affordable low allergy building specification. The work is based on the specification of low allergy houses at Toll House Gardens in Perth. The aim was to design dwellings that avoid, where possible, known and suspected building related allergens and minimise the conditions in which they can have an adverse impact. The specification was based on best available knowledge whilst conforming as far as possible to benchmark costs guidelines.

Contents

1 Introduction

1.1 illness

Evidence indicates that 1 in 13 adults and 1 in 8 schoolchildren in the UK currently suffer from asthma, whilst over 40% of people suffer from some kind of allergy. The number of sufferers from asthma and allergies has increased significantly in recent years. There is increasing evidence of a relationship between this increase in allergic reaction and modern buildings.

1.2 policy issues

Allergy and asthma raise a number of important environmental health and public health issues, especially given recent data on the very significant numbers of people affected. The subject also has relevance to UK policy on sustainable development.

- An affordable low allergy building specification would be a significant contribution to improving quality of life for a large number of individual sufferers, and their families.

- Improved information on design of affordable low allergy buildings could underpin future building regulations, including extending the scope of barrier free design to include those with breathing disability.

- It would contribute to the 'triple bottom line' of sustainable development if an affordable specification offset health costs resulting from sensitisation and illness. Performance and productivity are also vitally important issues of relevance to learning and teaching environments and to the workplace.

- A low allergy specification would represent a significant step forward in understanding of material and product production and the potential for import substitution and innovation in systems and materials for a range of building types. This has the potential to contribute to a general reduction in the polluting impacts of construction materials.

1.3 prevention

Given the extent of breathing related disability it is important that efforts are made to minimise sensitisation and reduce the triggers that promote attacks and the conditions that exacerbate them. It is also vitally important that affordability is addressed, so that solutions are available to all those disadvantaged. And design solutions need to be easily maintainable by owner/occupiers and carers.

Research has indicated that strict allergen avoidance can reduce asthma/allergy attacks & improve control. It may also reduce sensitisation and contribute to prevention of the development of asthma and allergies.

It is also known that creating alpine-like environments in hospitals, with a significant reduction in indoor allergens, is possible and that this has a beneficial effect on asthma/allergy.

This knowledge provides an enormous incentive to pursue a low allergen specification for housing. In respect of materials benign alternatives are available but cost can be a challenge. In respect of the temperature/humidity environment, it has generally been considered difficult to emulate the required degree of control in houses. In particular the reduction of moisture dependent moulds and dust mites is found to be difficult in Britain where ambient humidity levels are relatively high.

This research aims to examine whether by careful specification of materials and systems, avoiding triggers at the design and specification stage, and through good passive moisture control, allergen avoidance/control can be achieved in sufferers' own homes, even in the British climate.

1.4 outcome

The research looks at the interplay of health, energy and longevity issues in housing. It identifies that that proper attention to these issues can deliver better quality homes, which are cheaper to run and with increased longevity.

2 Allergy, Asthma and Buildings

2.1 allergy

Allergy is characterised by hypersensitivity to a substance that causes the body to adversely react to any contact with it. A wide range of substances cause allergic reactions including pollen, house dust mites, animals, aspirin and smoke. Allergy can affect mucous membranes, eyes and breathing and in extreme circumstances can have very damaging effects on the body.

2.2 asthma

The term asthma is used to refer to a variety of different clinical problems. There is no general agreement on the causes although genetics, smoking during pregnancy, pollution, diet, some drugs and the conditions of the internal environment have all been proposed as having an effect. An asthma attack is often an inappropriate reaction to common material such as dust, pollen, grass or pet dander. Notably formaldehyde and a wide range of glues are known to be hazardous to health generally and are thought to be asthma and allergy triggers for many people.

Asthma is characterised by periodic attacks of wheezing, chest tightness and breathlessness resulting from constriction of the airways. The basis of an attack is that the lungs respond to something which has been inhaled and which the immune system considers to be dangerous. The result is an inflammation of the airways, which causes them to narrow, and increased mucus production. The effect is extreme discomfort, as the sufferer has to work harder to get air, and in some cases results in death. The inhalers used as a response to an attack calm the muscles and reduce the inflammation.

The symptoms can occur immediately on exposure or after several hours. Following an initial sensitisation, asthma symptoms often develop at much lower levels of exposure than those that caused the initial attack. It can even be triggered by other factors such as cold air, exercise or smoke. Attacks may continue for years after the exposure which caused the initial attack and sufferers may then be disabled for all or part of their lives.

2.3 prevalence of asthma

The levels of asthma in the UK population have been rising for some time. There was a 7% rise in asthma amongst Scottish children in the three years from 1997, such that by 2000 146,000 of those aged from 2 to 16 were sufferers. Occurrence amongst adults remained constant at 164,000.

A number of potential causes of the increase in prevalence of asthma have been identified. Increased awareness and reporting, although relevant, is not generally believed to account for the entire rise. General levels of pollution, reduced resistance because of less breast feeding, and drugs in common use such as paracetamol, have all been linked to the rise.

One study by the UK Asthma Council compared groups in the Isle of Skye, and in central London and found similar prevalence of asthma. As the persistence of asthma was as great in a remote area as in central London the study concluded that external air quality could not account for the increased occurrence. They therefore began to seek to identify other causes.

A principal focus of attention is the indoor environment. We spend 90% of our time indoors:- at home, work or in leisure activities, and in confined spaces travelling between them. This can increase for the vulnerable, in particular the young, elderly and infirm. We encounter a wide number of air pollutants. It is known that breathing related illness such as asthma and bronchitis can be caused or aggravated by exposure to allergens in the home including dust mites, nitrogen dioxide and tobacco smoke.

The extent of the problem for an individual depends on a wide variety of influences:- previous exposure, the concentration and duration of exposures, their voracity, and their cumulative effects and predisposition. Research has indicated that strict allergen avoidance can reduce asthma/allergy attacks & improve control. It may also reduce sensitisation and thereby contribute to prevention of the development of asthma and allergies.

3 Indoor Environments

3.1 breathing related disability

Ideally housing and public buildings should contain no materials in their construction that are known to be, or could conceivably be, health damaging. Also the construction itself should be such that it cannot give rise to adverse health impacts at a later date, for example, by giving rise to condensation and mould in the indoor environment or fabric.

Perhaps surprisingly therefore, it is generally believed that the contemporary indoor environment, and the extent of time that we spend in it, is a significant source of problems in relation to breathing related disabilities. Yet, unlike the work environment, no controls presently exist. Indoor factors are known to play a role at three levels:

- Activating the immune system (sensitisation).
- Triggering symptoms (exacerbation) in those already sensitised.
- Maintaining a sustained inflammatory state

Given the prevalence of allergy and asthma in children it is surprising that no widespread initiative has yet been established to identify remedial strategies particularly when we are embarking on major infrastructural investments. If we are creating school and domestic environments that exacerbate breathing-related problems then children are likely to be the first to suffer. There are significant moral, social and legal implications.

3.2 changes to buildings

The indoor environment has changed over the period associated with the rise in asthma. Over a thirty year period we have developed buildings which are significantly less well ventilated, at a time notable for a dramatic upsurge in pollutants such as synthetic chemicals in furnishings, fabrics and finishes. A change in construction materials has also affected moisture in buildings. It is important to investigate how these changes might have contributed to exacerbating indoor allergy and to take steps to mitigate the problems.

3.3 triggers

A specification for a low allergy dwelling has to take into consideration all forms of possible allergic reaction stimuli, and eliminate them. The construction, furnishings and finishes should not contain any triggers , or allow them to develop. It therefore needs to go beyond existing standards to deliver an appropriate performance specification.

There are several major physical causes of asthma/allergy. These include house dust mites and mite faeces, moulds, spores, inorganic paint, adhesives and a wide range of organic compounds commonly found in indoor air. Specification of low emission materials helps to reduce off-gassing that can contribute to poor indoor air quality and trigger allergenic reactions.

An investigation into asthma in a tribe in Papua New Guinea provided strong evidence of a link between asthma and dust mites. The tribe, uniquely for the region, had an incidence of asthma 46 times that of the neighbouring tribe and 91% of the tribe showed strong evidence of sensitivity to dust mites. Also uniquely they used blankets that had been provided by missionaries. When tested the blankets showed high rates of dust mite infestation.

Conditions can be exacerbated by high internal moisture levels. This improves fungi and mite survival rates. This is a particular problem in the UK climate where average external humidity presents a problem when attempting to control moisture levels indoors. Some passive humidity control can be achieved through the use of appropriate servicing and use of hygroscopic materials.

There is evidence to suggest that adequate ventilation can reduce the impact of triggers existing in the home. The recent downward trend in ventilation has been driven by energy benefits, but it can lead to excessive moisture levels and the build up of triggers in the air. The specification therefore needs to incorporate servicing strategies that introduce adequate ventilation, without inefficiency or exacerbating pollution in the indoor environment.

4 The Project

The research is linked to the development of a housing scheme comprising fourteen low allergy, affordable dwellings at Toll House Gardens in Perth, designed by Gaia Architects for a housing co-operative to strict budget guidelines. The scheme is Phase 10 of a development that has seen a reversal of fortunes from deprivation and crime to a thriving community over a period of two decades. In 2003, the development was one of 5 projects in the world to be honoured with a World Habitat Award. www.bshf.org

The client was initially willing to support the research by allocating two houses to low allergy design and fit out. With certain cost assurances this was amended, and all of the houses were of low allergy design in respect of passive elements but the ventilation strategies differed.

Gaia Architects have substantial experience of healthy building design, including passive humidity control through the use of hygroscopic and low emission materials. Most recently this involved work in development of an innovative ventilation system, dynamic insulation, which has been used in five of the houses monitored. Ventilation heat recovery has been strongly promoted in the remediation of indoor air quality problems and five of the houses have incorporated it. The remaining four houses are naturally ventilated.

Considerable guidance was given to the prospective tenants about the housing, in advance of moving. Guidance notes were prepared on the ventilation strategies and their operation and on the opportunities for avoiding import of allergic materials into the new development. A number of tenants took advantage of guidance on flooring materials and bedding.

Monitoring equipment was placed in the properties at handover. All fourteen houses incorporated four loggers (temperature and r/h in the principal bedroom + living room). Two external loggers were also used to monitor the external climate. The evaluation included comparison of allergen & humidity levels in the houses with assessed critical levels from other research.

5 Principal Triggers

5.1 introduction

The most frequent triggers are house dust mites and pets. Moulds are also a significant concern. There are also a number of commonly used building products that can adversely affect the health of building occupants. These include insulation materials, wood based composites, paints and varnishes, furnishings, carpets, cleaning fluids and substances used for pest control.

5.2 house dust mites & dust mite faeces

Mites are a major source of allergens and they are extremely common in bedding, pillows, carpets, soft toys and furnishings. There is good evidence that they are the number one factor in asthma and respiratory related allergies and about 80% of asthmatics are allergic to them.

House dust mites are small, sightless, eight-legged arachnids related to ticks, spiders and scabies mites. They live in dust - dead skin cells, grit and soot - that accumulates in houses and are widespread in temperate and humid climates. They live for around 2-3 months and colony numbers vary according to the humidity cycle.

The dust mite faecal pellets contain high concentrations of an allergenic protein, particles of which can lodge in the lungs, where they can trigger allergic reactions. The allergens do not decay naturally and have been shown to be stable for 4 years. The particles are heavy, airborne only when disturbed, and do not stay airborne for long. The enzymes in the droppings destroy protective cells in the airways. Once this protective lining has been breached the enzymes are free to interact with the body's immune system - causing an allergy to develop.

A test has been developed to identify one allergenic protein - *DER p1* - present in dust mite faecal pellets. This is commonly used as a marker to the presence of other allergens and is as the basis for setting safety guidelines. Safety limits recommended by WHO indicate that prolonged exposure to

above 100 mites or 2 mg *Der p1*/g of house dust increases the risk of sensitisation. A level of 500 mites or 10 mg *Der p1*/g of house dust risks a severe allergic reaction.

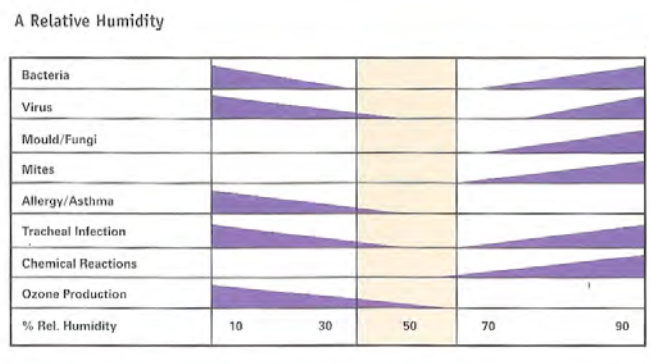
5.3 dust mite controls

A large number of studies have identified benefits to sufferers from reducing dust mite populations. Control measures have included: -

- Covering of mattresses and pillows
- Regular washing of bedding
- Avoidance of soft toys
- Humidity control to maintain low r/h
- Removal of carpets, soft furnishings
- Chemical control using pesticides and tannic acid
- Rigorous Cleaning & Vacuuming
- Use of electric blankets
- Temperature control such as freezing of bedding material

Dust mites are able to cling to fibres with suckers on their legs so while the pellets can be removed relatively easily by cleaning it is difficult to remove the mites themselves from soft furnishings, particularly carpets. Similarly, chemical treatments can kill mites but leave the faecal pellets intact. Other household pests such as flies, ants and cockroaches can harbour allergens in their faeces and in body parts and any cleaning regimes, which can help to reduce their presence, will be beneficial.

Ideal conditions for dust mites are 25°C and 80% humidity but they are tolerant of a wide range of conditions. They are well suited to living in common domestic environments as long as the humidity is adequate. They can be killed by periods of freezing.



High humidity provides conditions for survival, growth and reproduction of mites and hence greater faecal production and allergen concentration. They are most active in a band between 40% and 70% R/H. Mechanical humidity control that oscillates between these extremes may be detrimental.

Mites themselves have no respiratory system and use hygroscopic processes to replace moisture lost through evaporation, secretion, egg production and manufacture of faecal pellets. In dry environments they, and their food, begins to dehydrate. Their main food is human skin, which, in an environment where the RH is greater than 65%, is colonised by a yeast mould - aspergillus - that causes it to soften, making it easier for the mite to digest. Hence populations of dust mites rise and fall seasonally reflecting the changes in ambient relative humidity that affect both their source of food and their reproductive capacity. However, their population is also affected by local and global conditions internally. Any environment that can give rise to warm moist conditions will assist dust mite colonisation, so soft furnishings, including bedding, provide excellent conditions for their development.

A number of studies have indicated the benefits of controlling relative humidity with significant reduction in populations of dust mites and asthma symptoms. Many studies indicate an upper bound of absolute humidity is 7g/kg, however this is disputed by some in favour of a relative humidity criterion. The situation is complicated by the ability of the robust mite to withstand long periods at low humidity, overwintering for 7 month periods if necessary under laboratory conditions. Below a critical level the hygroscopic salts covering their bodies crystallise to help in waterproofing. Hence maintaining low humidity is only adequate to maintain a dust mite population in abeyance and not to eliminate it.

Importantly, the conditions in micro-environments in bedding, carpets, furniture and toys might differ significantly from general conditions in all or part of a home. Many therefore consider that global conditions are less significant than these local conditions where populations can thrive. Bedding is considered particularly significant because of the amount of time spent in, and humidity conditions associated with it.

It is necessary to supplement any overall humidity control with additional measures if the dust mites are not to multiply rapidly when and where conditions allow. Effective control would therefore seem to require a global control of ambient conditions to maintain the relative humidity at an appropriate level to prevent growth, combined with local management - through elimination. Vacuuming, washing, use of aracides, freezing of bedding, steam cleaning, mattress covers, removal of host environments such

as carpets and soft toys and furnishings and ventilation or structural repair of places where mites might colonise might all be necessary.

5.4 other important triggers

Fungi, Moulds and Spores…Fungal contaminants grow at moisture levels exceeding 60% RH. They produce a variety of toxins in the form of airborne spores that can adversely affect health and are associated with respiratory allergies. They are prevalent in damp areas such as poorly ventilated bathrooms and kitchens and where there is cold bridging. It is absolutely necessary to remove fungal growth in order to protect occupant health.
Pets …. Animal allergens are small proteins found in animal saliva, sebum, perianal glands and urine. They can be airborne for significant periods and as they attach to clothing, shoes and hair are often found in homes without pets. Significant research has gone into reducing allergens associated with pets, including specialist detergents, washing routines, reduced carpet, air filters and recently a genetically modified cat. A proven effective measure is to remove them. Up to 6 months is required to eliminate their presence.
Wall and floor coverings …Many finishes, decorating and bonding materials - paints, lacquers, adhesives and sealants - offgas a range of chemicals. Also many non-hygroscopic materials inhibit the ability of rooms to deal with moisture and contribute to an environment suitable for dust mites and fungi.
Formaldehyde…is present in significant quantities in a wide range of house furniture, insulation and floor and wall fittings including wood based products (particle board, plywood), urea formaldehyde foam for insulation and a variety of products used for disinfection, cleaning and painting. It irritates both the eyes and the upper or lower respiratory tract.
Nitrogen Oxide / Nitrogen Dioxide… by-products of gas combustion and may be present in significant quantities due to gas appliances. If alternatives to gas are not available then ventilation should be adequate and particularly rigorous regimes should be in place for servicing gas equipment.
Cigarette smoke or environmental tobacco smoke (ETS)... Smoke is a known irritant and smoking should be discouraged in the vicinity of sufferers.
Other Volatile Organic Compounds (VOC's) … Many building materials, paints and finishes, furnishings, cleaning fluids and cosmetics contain potentially harmful chemicals.

6 Design

6.1 the specification

Indoor allergy is closely associated with the presence of dust mites. A literature review showed that ambient humidity control is a necessary but not sufficient condition for control of dust mite populations and allergen densities. Complementary measures that deal with local environments particularly prone to dust mite colonisation are also necessary in order to have a positive impact on the lives of sufferers.

The design therefore needed to pay attention to both the global environmental condition, through a specification which aids moisture management through selection of appropriate materials, and also through local control which eliminates cold bridging, reduces the number of areas where dust mites might readily populate, aids good ventilation and prevents occurrence of high moisture environments. In addition sensitisation is associated with the presence of a number of chemicals. These were eliminated as far as possible from the design.

6.2 materials

The materials used in building have undergone perhaps greater changes than any other aspects of construction. At the beginning of the 20th century, about 50 materials were used in buildings. Now, some 55,000 materials are available, and about half are synthetic. This has a number of consequences.

Allergy - There is evidence of a relationship between modern building materials, the increase in indoor allergens and an increase in allergic reaction. A number of building materials are implicated including PVC, some paints, varnishes, insulation materials, timber treatments, wood composites and furnishings.

Emissions from building products - concentrations of more than 35 VOC's [including vinyl chloride, benzene, formaldehyde and toluene] are typically up to 10 times higher indoors than outdoors. These VOC's are associated with a wide range of detrimental health effects in humans and animals, [including

cancers, tumours, irritation and immune suppression] and many have been identified as emanating from building products. Appropriate choice of low emission materials can reduce ventilation requirements and this is an accepted trade off under the Norwegian building regulations. A number of schemes are now in place for classifying low emission rates. There is presently no limit for VOC emissions in the European Product Standard, although schemes exist in a number of countries.

Toxicology - There is also increasing evidence of the role that toxicology plays in pre-disposing people to asthma. Particulates of cobalt, nickel, cadmium and mercury have a profound effect on the immune system. A concern is that product information relating to health is usually derived from tests conducted on otherwise healthy people under laboratory conditions using a single substance. The affects on those potentially most vulnerable are rarely considered. Also, the risk to health from the 'cocktail effect' of the presence of a number of chemicals is rarely considered.

6.2.1 materials – design responses

MDF was limited to unavoidable aspects such as service cupboard doors and window cills. Formaldehyde free mdf was used. All particleboard is formaldehyde free.

Timber treatment has generally been avoided. Use of tanellised whitewood has been necessary for fire stops (the alternative being foam filled plastic). It was also necessary to use treated wood at the base plate of the bay windows of a wheelchair access unit where level access is required. The ground level is above the level of the base plate and there is risk of moisture ingress.

PVC is associated with pollution at all stages of its life cycle. It was avoided where possible. The budget did not allow for metal or clay drainage fittings or metal sockets so PVC was specified.

Factory fitted foam insulation was accepted on the hot water storage boilers as a benign alternative could not be sourced within the budget.

Solvent based paints were avoided. Walls and ceilings are finished with 'Green Paints' that contain no petroleum solvents, vinyl or chlorinated polymers found in conventional paints. Green paints use a resin based on

soya oil dispersed in water. The paints maintain the moisture balancing properties of 'breathing' walls and avoid the VOCs recognised as asthma triggers.

6.3 passive moisture management

Depending on factors such as materials selection, insulation, thermal mass, 'cold bridges' and air leakage, a building can cope with more or less moisture . Reduced prevalence of materials that have some hygroscopic properties is thought to be a factor in altering the composition of the indoor environment. Fluctuations in moisture content are greater and so are the problems caused by moisture. Worryingly this has meant that the management of moisture in buildings has increasingly been given over to energy and maintenance intensive mechanical systems. The increasing association of these systems with further pollution is encouragement to look to passive control through hygroscopicity and thermal mass.

6.3.1 hygroscopicity

Hygroscopicity describes the ability of some materials to absorb moisture when the humidity rises and to emit it when the air becomes dry. Materials, which react quickly to changing air moisture contents by either taking up or releasing moisture, are especially valuable as they can help to stabilise the relative humidity and to prevent moisture related ill-health and damp-related damage in buildings. Some materials can hold quite large quantities of moisture without any special risks of biological activity or degradation. Materials such as timber, plaster, aerated concrete, lime render, clay, wood-fibre boards, wood-fibre cement, earth and textiles have good hygroscopic properties, so long as they are not given impervious coatings, such as conventional varnishes, paints, stabilisers and others do not impair these.

When the indoor atmosphere is likely to be subjected to sudden moisture loads the damp-buffering capacity of materials becomes particularly important. Bedrooms that have been empty all day experience a sudden change in moisture load when a person or persons go to bed. The impact of this moisture can be particularly troublesome if the bedroom is unheated, poorly ventilated and thermal insulation poor, so that condensation almost inevitably forms, followed equally inevitably by mould growth. Moulds do

not need condensation in order to develop – they can grow on a surface if the humidity reaches 70%.

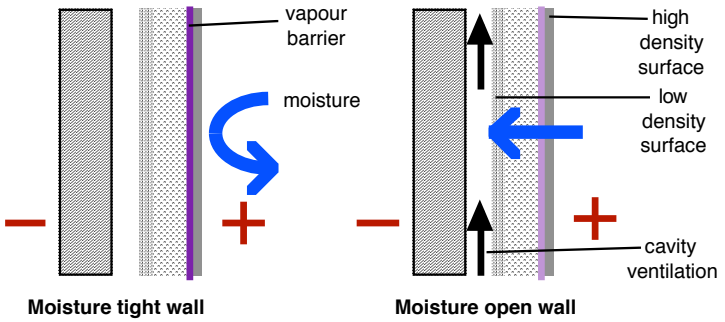
There is a dearth of information on the contribution of building materials to moisture stability in indoor environments. Knowledge of hygroscopic behaviour, which is sometimes referred to as 'moisture mass', is presently on a par with understanding of thermal mass perhaps three decades ago – when research into admittance was first initiated at BRE. Theoretical research was undertaken in the early 1990's at BRE into absorption and desorption. Some work has been undertaken into appraisal of hygroscopic mass in middle Europe and in Finland but the range of materials is limited and little connection appears to have been made with issues of temperature swings. Further information is required in English to assess the potential contribution of the effect and to develop it into a usable design tool.

More information can be found in Light Earth Construction Gaia Architects January 2003 at www.lightearth.co.uk and Sustainable Construction CPD Module 6: Ventilation and Cooling available from www.gaiagroup.org

6.3.1.1 hygroscopicity - design responses

A number of design aspects relate to the passive moisture control.

- Some types of construction can lead to build up of moisture in the structure and this may have implications for durability of the structure and for build up of health threatening conditions. Concerns for indoor moisture management make the use of moisture transfusive (breathing wall) construction preferable to other forms of construction. It was developed for use with timber construction in order to ensure that moisture traversed a structure from inside to outside and moisture build up was prevented. It has the added benefit of avoiding insulation materials that contain known triggers such as formaldehyde and some plasticisers. Insulation levels are 200mm throughout walls and roof giving a U value of 0.15W/m^{2}K. The windows have a U-value of 1.6, doors 0.6 and ground floor 0.26 W/m^{2}K.



Breathing wal Principle.
From air tight to air open there are key points in the density differences of materials The flow of either moisture or air - or both - is created by a pressure differen across the wall.

Diagram: Contributed by Gaia Architects

➢ Timber stud walls using 147 x 45 mm studs with 45 x 45 horizontal battens fully insulated, minimising cold bridging.

➢ Wallpaper and glues were avoided in the interest of maintaining 'breathable' wall surfaces and avoiding off-gassing. No intervention on finishes is allowed during the contract liability period of 12 months and during this period the tenants will be educated about the various finishes and available options.

➢ Lime or clay skimcoat to internal partitions was envisaged for additional moisture regulation in bathrooms / kitchens. Unfortunately it was deleted in order to achieve a cost saving.

6.3.2 thermal mass

Thermal mass has an impact on moisture management. Rapid cooling of buildings gives rise to fluctuations in relative humidity that are detrimental to buildings and occupants. Building materials can sustain very large populations of micro-organisms, e.g. plastic membranes, glass fibre etc can have colonies of fungi and bacteria that are 1,000-50,000 times greater than natural materials.

6.3.2.1 thermal mass - design responses

A number of design aspects relate to thermal mass.

➢ Ground floor insulation has been installed under the slab to prevent sudden temperature and humidity changes. It allows the concrete to absorb and retain heat, giving it off slowly again over night when the central heating

is likely to be switched off. The insulation itself was intended to be expanded clay, but again this was not possible within the client's budget. Expanded polystyrene has been installed, the compromise was accepted in this instance, as the foam is not in contact with the indoor air and therefore pollutants from the insulation will not be able to contaminate the indoor climate.

6.4 allergen removal

It is intended that the internal climate conditions will make it difficult for moulds and mites to colonise and so measures have been taken to make cleaning easier. Smooth coverings (tiles, timber floors, lino) aid the cleaning up of triggers (and their producers).

Smooth floor coverings were installed where possible. As the client policy is to provide only a sub floor influence on the coverings was limited. However, with the assistance of manufacturer Forbo Nairn, kitchens, bathrooms and hallways were generally finished with linoleum installed using a benign glue which is not yet readily available in the UK, but produced for the Dutch market. A meeting with tenants included advice on suitable floor finishes and a small number requested that lino also be installed in their bedroom areas, again completed with the assistance of Forbo Nairn. Tenants were advised to install smooth floor coverings in those rooms that are not delivered finished within the contract.

The bathrooms in the two wheelchair units were finished with vinyl as safety flooring is required in these areas. As yet the production procedure of linoleum does not allow for the inclusion of chippings to provide an appropriate safety grip when wet.

The service pipes in bathrooms have been boxed in providing smooth, easy to clean, surfaces.

Wall mounted storage and panel heaters provide smooth, easy to clean surfaces.

Allergens/triggers may enter the dwellings from outside e.g. pollen or pet dander brought in by visitors as well as bedding and carpets brought from previous properties. In order to minimise the problems, the tenants were offered a free steam cleaning service, for the first 12 months of occupancy, of items identified through tests as affected.

6.5 ventilation

We ventilate buildings principally to remove moisture & odours that are generated indoors that can be hazardous to health and buildings, or simply unpleasant. But, fresh air is also known to be vitally important to peoples' perception of a space, their health & well-being, and their productivity.

In recent years, openings for fires have been sealed or designed out. Existing houses have been more tightly sealed to achieve much needed energy efficiency improvements. Newer houses have much higher air tightness standards. These changes have dramatically reduced the amount of ventilation in most homes. Along with an increase in internal washing and drying this can lead to excessive moisture levels and a build up of pollutants.

There is a need to have high levels of ventilation without the energy loss with which it can be associated. Mechanical ventilation systems have also increasingly been seen as part of the problem. In a study of 15 offices: - 25% of the pollution derived from smoking, 20% from materials & furnishings and 42% from the ventilation equipment.

The ventilation strategies are of particular interest in respect of their efficacy, affordability and energy efficiency, and importantly their potential to avoid introducing further pollutants. A number of options were investigated. Three ventilation strategies were compared over the monitoring period. Five units were fitted with Whole House Mechanical Ventilation with Heat Recovery (MVHR) provided by Baxi free of charge. Dynamic insulation has been employed in 5 houses. The remaining 4 dwellings are ventilated conventionally via trickle vents in the windows and extract fans, to technical standard requirements, in the bathroom and kitchens.

Mechanical Ventilation with Heat Recovery (MVHR)

MVHR transfers heat from outgoing air to pre-warm incoming air providing up to 70% heat recovery. It can reportedly control relative humidity and remove airborne irritants. A pollen filter is supplied for filtration of the incoming air. The system installed is a Baxi Whole House system. It aims to extract air from the areas of greatest contamination, and to replace it with an equivalent volume of pre-warmed fresh air into the living areas. The ventilation extract is installed in the cooker hood and extracts continually. Air is supplied at 0.5 ac/h. Extending the cooker hood boosts the extract and air is supplied at 1.5 ac/h.

Dynamic Insulation

Dynamic insulation is a technique for ventilation of buildings in which air is drawn into a building through the fabric, in this case a porous ceiling membrane spanning the whole housing unit. The loft space of the dwelling is slightly pressurised by a fan and the roof void must be completely sealed. The ventilation air is warmed as it passes through the ceiling membrane. When used in combination with hygroscopic materials it has been shown to provide a buffer against the rapid changes in moisture that are known to encourage growth of allergy triggers. Extracts in the kitchen and bathroom operate continually at 13.5W and boost in response to high humidity to 35W.

Conventional Ventilation

The remaining units are conventionally ventilated with trickle ventilation in windows and extract fans in bathrooms and kitchens.

6.6 air tightness

Alongside a designed ventilation strategy it is necessary to ensure that unwanted air exchange into the structure and between inside and outside is minimised. The measure of airtightness primarily used is the "Air Permeability", expressed as the airflow per hour per square metre of total surface area, at 50 Pascals imposed pressure differential (m^3/ hr/ m^2 @ 50 Pa).

- The target Air Permeability value set in Parts L1 & L2 of the 2001 Building Regulations (England & Wales) is 10. CIBSE TM23 sets air permeability targets of: Dwellings "Good Practice" 10 (m^3/ hr/ m^2 @ 50 Pa) and "Best

Practice" 5, reduced to 5 and 3 if they use a balanced whole house mechanical ventilation because of the energy implications of mechanical ventilation.

- The Association for Environment Conscious Building (AECB) recommends a "Factor 4" target for Air Permeability of 3 (the same as the Swedish Building Code enacted in 1978!) and a "Factor 8" target of 0.5 comparable with best international practice.
- The Canadian Super E standard, requires all dwellings to be fitted with MVHR systems and to achieve an airtightness of 1.5 ACH @ 50 Pa.
- The German Low Energy House has an Air Permeability target of 3.
- The German Passivhaus standard is a maximum Air Permeability of 0.6.

It became clear during air pressure tests that more attention is required at all stages from inception, through detailing and to site supervision to ensure that requirements are delivered. The industry still largely fails to understand the issues of air tightness and takes a relaxed attitude to these requirements. That aside the builders were extremely willing to address the issues once they were highlighted and both they and architects learnt a great deal from the experience which they are keen to implement in further projects.

6.7 heating

In general the consensus is that low allergy designs should avoid combustion products in the atmosphere. Hence, gas heating and pilot lights associated with gas cooking should be avoided. The design and research team therefore deemed electric heating to be the most suitable form of heating for this application to eliminate the risks to asthma sufferers .

The use of electricity for heating cannot be condoned in most circumstances. It generally incurs higher running costs and should be avoided particularly if low-income tenants are affected and fuel poverty is an issue. Compared to other fuels electricity results in higher CO_2 levels if produced conventionally. Support was sought for on-site generation or a cost neutral green electricity. The issue raises questions out with the boundaries of the research. Tenants were encouraged to choose electricity from renewable resources to achieve a carbon neutral system. However at the time of handover no grid green electricity was available in Scotland. In the intervening period suppliers have entered the market but costs remain prohibitive.

Special attention was required to insulation levels and other factors in order to achieve the necessary SAP rating. High levels of insulation with low

infiltration and controlled ventilation have kept the heating requirement to a minimum. It proved possible to design electric heating for the properties and achieve SAP ratings of 85-95, which is above Communities Scotland requirements. This puts into question the stringency of these requirements. If the properties were heated with gas then the ratings would have been in the range 113 - 121. A higher general requirement and support for contextually driven solutions would seem appropriate especially if the overall objective was benchmarked against CO_2 policy targets.

It would be highly regrettable if low allergy design were to lead to an increase in expensive and polluting conventional electric heating yet the alternative is to expose the vulnerable to a known pollutant. This presents problems at the heart of discussions on energy efficiency measures, priorities and policy. It has been apparent for decades that policy measures to deliver cost effective energy solutions and reduce carbon emissions have been lame and that in most areas the UK government has dragged its feet compared with best practice elsewhere.

7 Cost

7.1 introduction

It is vitally important that solutions are affordable to those disadvantaged, yet, many approaches to low allergen design involve considerable additional expense, in both design and management, and put solutions out of the reach of many sufferers and carers.

This project took very seriously the objective of achieving a cost competitive solution with low maintenance requirements, in order to enable implementation by owner/occupiers and carers and increase willingness amongst Registered Social Landlords and other clients to implement these measures. Downward pressure on the cost of house construction has perhaps never been greater than at the present time when land deals are the major source of profit. Consideration of all the relevant factors would also result in a significant improvement in building integrity and longevity in many cases.

7.2 delivered cost

The delivered costs were well within the guideline cost range for mainstream general purpose social housing in the region. However, a number of features that were included in the original specification, were excluded from the final design due to cost limits. Some of these have a bearing on indoor air quality, others were reductions having a bearing on overall adverse impact of built development. In order to have a genuinely benign specification that would meet the requirements of sustainable construction outlined in government policy the designers would seek the following changes: -

- Insulated Timber shutters to reduce the need for curtains, and assist in reducing temperature swings..
- A renewable source of electricity to support the selection of allergy friendly electric heating or other carbon neutral options.
- Aluminium /clay drainpipe rather than PVC.
- Metal internal sockets rather than PVC.
- Floating timber floors (avoiding need for glues) rather than formaldehyde free chip board (fixed).

- Benign insulation around boilers.
- Sheep wool insulation around windows to provide air seal.
- Formaldehyde free doors could not be identified.
- Non-slip linoleum – none yet available.
- Affordable formaldehyde free kitchen units.
- Internal block work partitions finished with lime plaster
- Plasterboard in bathrooms / kitchens to be skim coated with lime plaster for moisture regulation.

In total the reductions saved £64,500 on the cost of the development, equivalent to around an additional 11% of the cost. The single most significant item was the shutters. However, notwithstanding these elements a great deal was achieved within the budget.

7.3 social costs and the environment

The financial cost of the development was compared to the cost of treating asthma-related problems. The National Asthma Campaign statistics indicate that in the UK 1 in 25 adults and 1 in 7 children have asthma. It accounts for 1,500 deaths each year. Also 7 million lost work days due to asthma result in £350 million in lost productivity and costs approx' £60 million in sickness benefit. The costs of asthma treatment to the NHS is £850 million a year.

7.4 materials

An area that has been largely neglected is that of product development for construction. Many environmental products still lack competitors and are perceived as specialist. They are typically priced at a premium over less benign alternatives, making sustainable construction in general more expensive than conventional building. The majority are produced overseas adding often significant and prohibitive transportation costs. There is a need to investigate opportunities by which UK suppliers of manufactured goods to the construction industry can gain a significant share in the rapidly expanding environmental product markets at home and abroad. Identification of cost effective opportunities to reduce environmental impact would enable manufacturers to retain or expand their market position against imports and to increase exports. The effect of this will be to reduce adverse environmental impact of materials, products and components, to improve choice and reduce costs of sustainable construction.

8 Case Studies

The Bourne House

Architects: Gaia Architects
Photo : Gaia Architects

An environmentally friendly house built near Aberfeldy by Gaia Architects.

Constructed in 1992 and consisting of 2 storeys with a large passive solar conservatory, timber frame and breathing walls. It won the House of the Year in 1993.

Daylight is allowed to flood into the interior through the double height conservatory, which doubles as part of the living area and the stairwell. Large windows elsewhere in the house, especially the full height gable windows in the bedroom, combine to give a bright and welcoming interior.

Kitchen for a Chemically Sensitive Client – Medina, WA

Rob Harrison Architects

photo courtesy of Rob Harrison Architects (photographer Michael A Moore)

This project involved the renovation of a kitchen and two bathrooms for a client who suffered multiple chemical sensitivity (MCS).

Before construction started, the client tested all the materials to be used in the renovation to ensure that she would experience no adverse reaction. Of the 120 materials tested, only five were rejected. The following measures were taken to ensure a healthy and safe environment for the renovation:

- All materials and finishes used throughout the renovation had a very low toxicity level.

- Cabinets made from formaldehyde-free Medite II, were bonded together using a low toxic adhesive and coated with a low-toxic finish.
- The kitchen floor was made from sustainable harvested cork, with a low-toxic adhesive and a low-toxic clear finish.
- All joints were bonded with a low toxic compound.
- The natural wool carpet used in one area was fixed with tacks and placed over a hair and jute pad.
- A water filtration system was designed in to the renovation.
- Ducted fresh air intake supplies make-up air when the range hood is turned on to prevent back draft.
- Materials containing CFCs, urea formaldehyde, benzene, toluene, carbon tetrachloride, styrene-butadiene, or trichloroethylene were excluded.
- A ban was placed on petroleum-fuelled generators and heaters on site.
- A ban was also placed on smoking and the use of fragrances.
- The use of pesticides, herbicides and noxious cleaning products were banned.

Allergy House, Bonn, Germany
Weberhaus Gmbh & Co. KG
photo courtesy of Weberhaus Gmbh & Co. KG

Located in Bonn, Germany this kit built allergy house was developed for a family of allergy sufferers and provides a basis for ALLÖKH certification.

The house has been designed to be ecological but has also avoided the use of materials that may trigger allergen reactions such as sheep's wool. The following features have been incorporated into the design to reduce the exposure of the occupants to allergens including:

- A low allergy plot: suburban with few trees and south facing to maximise solar gain.
- The use of untreated timber.
- The use of low emission paints.
- Wall to wall tacked carpets avoiding the use of glue.
- Taps and other fittings do not contain nickel or non-ferrous heavy metals.
- Pollen filters have been placed on windows.

- Walk in cupboards have been located in front of bedrooms to allow for 'contaminated' outdoor clothing to be removed before entering the sleeping area.
- Central vacuuming system.
- Whole house ventilation system.
- The use of radiators that can be folded down to allow cleaning to take place behind them.
- A hobby room with a separate entrance has been located in the cellar of the house providing an isolated space for activities that may create a health issue if carried out in the main house.

Sunnmorgata 1, Lista, Norway

Civ. Arik. Alice Reite MNAL

Photos Alice Reite

This project involved the renovation of an inner city apartment in Oslo.

- Non-toxic, natural materials have been used throughout the renovation including clay, ecological paints, oils and woodwork.
- Over 100 types of clay plaster were tested to find the best mixture – this was part of wider research project.
- Humidity is so well controlled that there is no misting of bathroom mirrors, even with no extraction fans.
- Walls are insulated with wood/wool cement boards and chicken wire with reinforcing and clay plaster.
- Heating cables have also been placed in the plaster creating a surface that delivers an even and low heat without increasing dust circulation or creating dust collecting surfaces.
- Throughout the whole apartment, plastic materials have been avoided except for a plastic membrane under the floor in the bathroom.

'Non-Toxic' House, Stavanger, Norway
Gaia Lista, Norway
photo courtesy of Gaia Lista

The 'Griftfri' house in Stavanger was built with the aim of creating a home that would be environmentally sound as well as providing a healthy habitable environment.

The following features have been adopted as part of the design:

- Lime concrete and lightweight aggregate blocks have been used as the primary construction method. Both of these are classed as 'breathing' materials therefore aiding the regulation of moisture.
- All internal and external walls have been painted with non-toxic silicate mineral based paints.
- Internal timber finishes are coated with lye.
- Flooring is either wax or oil timber, or loose laid tiles.
- Cellulose fibre insulation is used in all the walls.
- Sheep wool has been used to provide draught sealant around the windows

9 Legal Case Studies

There have been a number of legal cases brought against landlords, homebuilders and insurers over health problems originating from poor indoor air quality. Most examples from the United States where legal action on indoor air quality is more common, and often results in the payment of large damages. One groundbreaking case is in the courts in Britain, and if successful, will likely witness a large increase in indoor air quality (IAQ) litigation in the UK.

A large number of cases in the US concern toxic mould growth and associated health problems. Toxic mould is widely regarded as a medical hazard and is more open to litigation, than other indoor pollutants such as dust mite allergens and VOCs where medical research is complex and less conclusive.

In the US the number of mould related claims has increased rapidly with 7143 cases being reported in 2001 compared to only 3 cases a decade before. Substantial sums have been awarded to plaintiffs in a trend that has seen contractors placing mould exclusions in their contracts and insurance companies raising premiums or adding mould exemptions to their policies. It is unclear whether litigation will prompt improvements in construction techniques and indoor air quality or if other measures will be sought to escape mould liability.

Call vs. Prudential

This was the first major IAQ case argued before a jury in the US. The case generated important IAQ related law . The main charges of negligence brought by the plaintiff included:

- The use of building materials that off-gassed formaldehyde and other noxious chemicals
- Failure to notify that the building was not suitable for occupancy due to noxious fumes and chemicals infiltration.
- Failure to supply adequate levels of fresh air.
- Failure to act on reports of tight building syndrome (TBS) and sick building syndrome (SBS).
- Failure to provide information on the health effects of TBS and SBS.

Liability for problems with the HVAC system was extended to the manufacturers and sellers of the system as well as everyone involved with the construction and design of the system including architects, engineers and installers.

DuPage County Courthouse v. Hellmuth Obata & Kassabaum

Staff experienced symptoms of SBS shortly after moving into the new courthouse in Illinois with reports of over 400 occupants suffering from headaches, nausea, dizziness and respiratory irritation. In March 1992 the building was evacuated with several building occupants requiring ambulances. Later that year, several of the occupants filed personal injury lawsuits against the architect and contractors (including the HVAC contractor) alleging that the design of the ventilation system and presence of VOCs were responsible for the illnesses they were experiencing. The County also filed a lawsuit against the architects and contractors seeking $3 million for fixing the ventilation system. The County failed to win damages, the final verdict stating the County was responsible, attributing the problems to the measures taken in response to earlier concerns over IAQ including the chemicals used to clean furnishings and alterations to the mechanical systems. Only minor damages against the architect and contractor were awarded due to faults in the air handling systems. However a number of individual suits were settled out of court. The publicity that this generated played a key role in insurers and others taking SBS more seriously.

Mackenzie vs. Glasgow City Council & Glasgow HA

In the first case of this kind in the UK, Linda MacKenzie, a Glasgow mother, is taking the local council and housing association to court over damp conditions in her home. Her seven-year-old son developed asthma and it is claimed that the damp conditions are responsible. High levels of exposure to dust mite faeces have been identified in the claim as being responsible for the development of the child's asthma. Dust mite samples taken from the mattress in the child's bedroom found 1,400mcg of Der p1, 700 times higher than the World Health Organisation safety levels. The case is aiming to prove that the landlord failed to carry out repairs that might have improved the conditions within the house and are therefore responsible for the child developing asthma. Although the damages sought are modest when compared to the cases in the US (£50,000), it is hoped that if causality is found it will lead to landlords reviewing poor living conditions.

515 Park Avenue, New York

515 Park Avenue is known as the world's most expensive condo building, where the cheapest units sell for $8 million and require a $40,000/month maintenance fee. However, cracks in the foundations, poorly insulated pipes and improperly sealed walls allowed water to seep into the building resulting in mould growth. 8 of the buildings 38 apartments had to be evacuated and many common areas had to be sealed off over potential health concerns. Residents and the buildings board of managers started litigation against the buildings sponsors and contractors in late 2002. A second case asking for a phenomenal $2 billion in damages was also filed by one resident against the buildings board of managers as well as against the building sponsors and contractors.

Town & Country Apartments

During her period of stay in a Town & Country apartment an occupant reported suffering from constant headaches and her infant daughters both suffered from frequent coughing and nosebleeds. After discovering that the property was infested with aspergillus and penicillium moulds the family decided to move out and file a lawsuit against Town & Country and Preis Properties Officials. The suit claims that after receiving complaints over a mould problem in the property, the management ignored the problem except to advise the occupant that she could exercise her right to terminate her lease. The occupant is seeking damages from her landlord for moving expenses, increased monthly rent and the cost of replacing their personal property that had become infested with mould.

10 Next Steps

There is a need for an extensive study into the medical success of low allergy design and a comprehensive review of medical research into adverse health effects of the built environment to clarify current medical opinion on the success of low allergy design measures.

It is timely and in line with the precautionary principal to develop a large-scale affordable low allergy housing initiative based on best available knowledge, in line with other precautionary initiatives.

An evaluation of low allergy building techniques and ventilation strategies on the health of participants, with established respiratory conditions, on a larger, more long-term trial would be a valuable next step.

The experiences here, and associated research output, leads the research team to conclude that leaky buildings are the norm and that the health and longevity implications for timber frame houses are very significant. It is important that this issue is dealt with through assessment of existing stock and through provision of appropriate design details to address long term heath as well as energy issues.

A conflict has been identified between the requirement for low unplanned ventilation and the requirements of fire safety. The tightness of the Toll House Gardens buildings meant that automatic door closers on fire-doors were not functioning. The solution was to use much stronger door closers but these are difficult for some of the more fragile occupants to open and close very heavily. They are not popular with the occupants and a more satisfactory solution should be sought in the longer term. As the problem was not predicted, and because air tightness is not a building regulation issue, the builders were not obliged to make the necessary repairs and the expense had to be met from the project budget. The building regulations division may wish to take this into consideration.

There is opportunity for research to be carried out into the policy/regulations that have encouraged the development of low allergy projects in other

countries and any fiscal concessions that have been made or standards that have been imposed. This would aid the development of UK policy aimed at encouraging healthy building design. It would be useful to have an evaluation of the achievements of these projects and any subsequent monitoring that has been carried out.

As all of the buildings were designed for passive moisture control – regardless of the ventilation strategy - it would be useful to more fully compare the relative humidity data with a control set where this was not a consideration. The fact that the environmental conditions in the naturally ventilated houses at Toll House Gardens compare well with the active ventilation strategies used in the other houses suggests that the passive moisture control may be having a significant effect. This is worthy of further investigation to quantify the effect. A desk study of current research perhaps followed by some laboratory comparison of hygroscopic and building materials could provide invaluable information to designers and clients. The implications for ventilation control and moisture management in buildings could be profound with potential capital and running cost savings as well as improved indoor climate.

This was a short term study. It would be useful to supplement this report with e.g. a 5-year follow up visit to Faiarfield to establish whether any significant mite activity has occurred and to verify whether the conditions within the dwellings are capable of maintaining low allergen levels over the long-term.

11 Further Information

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Full references are provided in Halliday S.P Chapman B Jones P Low Allergy Housing 2004 Gaia Research which provides the full background to the research.

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11.2 web sites

Housing research summaries
www.housing.odpm.gov.uk/hrs

Pilgrim Bed Co. The Pilgrim's Mighty Book - an educational A guide for parents or guardians
www.pilgrimbed.com

Dust Mite News
www.arct.cam.ac.uk/research/mite

Asthma in Ashford
http://www.asthmainashford.co.uk/index.htm

Building America (publications) – US department of Energy
http://www.fsec.ucf.edu/bldg/baihp/pubs/

Department for Environment, Food and Rural Affairs (DEFRA) – Air Quality
http://www.defra.gov.uk/environment/airquality/

South Gloucestershire Council – Asthma Housing and the Environment
http://www.southglos.gov.uk/environmental_protection/asthma.htm

Envirodesic
http://www.envirodesic.com/index.html

International Institute for Bau – Biologie
http://www.bau-biologieusa.com/

American Lung Association Health House
http://www.healthhouse.org/index.asp

Healthy Home & Workplace
http://www.healthyhouse.com/

BuildingGreen.com Indoor Environment Quality
http://www.buildinggreen.com/menus/subtopics.cfm?TopicID=5

Healthy Building Network
http://www.healthybuilding.net/

International Society of Indoor Air Quality and Climate
http://www.ie.dtu.dk:80/isiaq/

Consumer Voice USA
http://www.consumervoiceusa.com/HotTopicsHTML/SubTopicMold/ToixcMold/TMcases.html

Building Air Quality
http://www.baq1.com/

Legends Environmental Insurance Services
http://www.legends-enviro.com/default1.htm

Environmental Health Perspectives
http://ehp.niehs.nih.gov/members/1999/suppl-3/465-468rylander/rylander-full.html

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http://www.euro.who.int/air/Activities/20020620_1

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