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CURRENT STATUS OF RESEARCH INTO INDOOR AIR QUALITY

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Pure air to breathe is a fundamental human need. The critical aspect is not oxygen content, which is hardly ever inadequate in buildings, but the presence in the air of various substances which effect health. The adverse effects of some pollutions were recognised in antiquity and in the classical periods many buildings enjoyed excellent ventilation.

In medieval times, ventialation standards were low and there seemed little appreciation of the consequent health effects. The industrial revolution produced grossly unacceptable air quality in many manufacturing buildings and during the same period it was recognised that inadequately ventilated and damp conditions in non-industrial buildings gave rise to infection and disease.

During the 19th century major public health efforts were devoted to introducing legislation which would control potential sources of pollution, provide adequate volume of space for occupants, and ensure that sufficient fresh air could enter the rooms. Domestic, commercial and industrial buildings were all the subject of this type of regulation.

In industrial buildings a succession of Factories Acts and the Offices, Shops and Railway Premises Act have controlled sources of pollution, required "effective and suitable" provisions for ventilation and enabled government regulations to be made and kept up-to-date, specifying temperature, humidity, space, ventilation standards and exposure levels for any circumtances thought to require control. A system of inspection was established to assist in maintaining standards.

In non-industrial buildings there are no statutory quality standards. In buildings for public entertainment minimum rates of flow per person are required. In other cases, if the ventilation is provided by mechanical means, the system can be designed to meet the volume of air flow recommended by one of the authorities in the field. The great majority of buildings, however, are ventilated naturally and there are no explicit standards of air quality or even rates of ventilation.

The legislative provisions for non-industrial ventilation were indirect. They specified minimum open areas around buildings, minimum headroom or volume, minimum opening areas of window and, for some types of room, ventilators to the fresh air. While these provisions do clearly affect ventilation rates the degree of ventilation resulting cannot be predicted and will vary very greatly depending on the building form and the surrounding buildings and topography.

Together with other similar measures the ventilation provisions were highly successful. In spite of the limitations described, the ventilation provisions which resulted from legislation were highly successful. Clearly they served an excellent purpose and, for a long period there was, rightly or wrongly, no concern about health risks arriving from inadequate ventilation standards in new buildings. Much of the dramatic improvement in public health which has taken place during the last hundred years is due to improved building standards in which ventilation has played a critical part.

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Recent changes

Apart from the abandonment in the Building Regulations of 1965 of the call for a flue or ventilator in every habitable room the statutory requirements for ventilation have changed very little for many years. However, the performance requirements and the nature of the building fabric and installation have changed very markedly. The energy crisis has imposed a need to reduce ventilation rates to a minimum, which conflicts with the hygenic need to provide generous air change rates. There is a strong tendency for new buildings to be more airtight. Windows are carefully designed to seal efficiently and in existing buildings draught prevention is a very cost-effective method of energy saving. The inclusion of small opening lights in windows called "night ventilators" which used to be universal has been discontinued in new buildings for reasons which appear to be aesthetic rather than functional. All carefully considered and developed measures which helped to provide controllable ventilation in winter conditions appear to have been forgotten.

In addition to these direct influences several other developments affect ventilation, particularly in dwellings. Unlike open fires or stoves most types of heating installation currently being installed do not promote ventilation. The ease with which modern heating installations can be controlled, coupled with the substantial expense of central heating, results in a tendency to turn off the heating whenever possible.

This is emphasised by the current patterns of living where a substantial proportion of dwellings ~~is~~ are unoccupied during the day. In these cases, for security reasonsm, ventilation is likely to be further restricted by closing the windows. The load of pollutants input to the air has also changed. More frequent bathing reduces the concentration of body odour which used to be the main determinant of ventilation rates, but many manufactured items both incorporated in the building fabric and in the form of furniture may give off polluting substances such as formaldehyde. While the actual levels achieved depend very much upon method of working, it is likely that machine dish washers and clothes dryers, if not ventilated to the exterior, contribute more moisture to the internal air of dwellings than traditional processes. Many consumer products, particularly aerosols and cleaners contribute to pollution in the air. In larger buildings air conditioning systems and even shower sprays can house and distribute biological pollutants. Instances of airborne infection from spray chambers and shower heads have received wide publicity. The higher temperatures prevailing in buildings encourage some forms of biological pollution.

In the case of long established pollutants where the level of input has not changed significantly, the effect of reduced ventilation is to give higher concentrations in the internal air. This affects the emission from tobacco smoke, combustion products from flueless heaters and gas cookers, radon from masonry materials and foundations, moisture and biological pollutants.

In most cases pollutants are introduced directly into the atmosphere. In some cases, they arise as a result of conditions which might not, themselves, be regarded as contributing to contamination. The spores from moulds growing as a result of surface condensation form a good example. Current medical opinion regards these spores as potential allergens capable of affecting a significant proportion of building occupants. The condensation giving rise to them, however as a result a combination of moisture in the air and cold wall or ceiling surfaces. It can occur when the moisture levels would be regarded as normal and wall temperatures are not usually regarded as relevant to air pollution. A very detailed understanding of the ways in which buildings behave is needed to anticipate this problem. Water in air conditioning systems and even the small quantities retained in shower heads can be the cause of boilogical pollution particularly if the water is maintained at acomfortably warm temperature. In both these cases the effect of the arrangements in the building is to enable contamination present in the atmosphere in very small quantities to multiply and become concentrated in the buildings. It demonstrates, however, that in designing for high standards of air quality attention is required to a wide range of buildings features, not merely the provisions for ventilation itself.

As a result of these changes the air breathed by the occupants of buildings, regarded for many years as entirely safe and satisfactory, now gives rise to considerable concern. Since the requirements of health and energy conservation are opposed there is no easy way of approaching the problem by determining a simple maximum level which while it must not be exceeded, nevertheless allows a wide range of acceptable results. The ventilation rate to be achieved have to be within a very narrow optimum range.

Control of Air Quality and Ventilation

At first thought it is surprising that there are no general provisions in building regulations giving direct control of ventilation rates. It is even more surprising that, since ventilation is one of the major aspects of heat loss from buidlings, it has not been controlled from the energy conservation viewpoint. The contrast with thermal insulation of the building fabric, which has been the subject of frequent and increasing stringent statutory requirements, is very dramatic.

The explanation is a simple one. It is impossible for designers to specify the form, materials and workmanship of the building in order to achieve a specified natural ventilation rate and it is very expensive, complicated and time consuming to measure ventilation rates. Consequently, universal, or even selective checks of actual building performance are impracticable.

There would be no value in statutory ventilation requirements which could not be designed in or checked. On the other hand, the consequences of inadequate indoor air quality in terms of health have been amply demonstrated for several pollutants and there is increasing concern about many more. Standards of air quality should be controlled and if existing knowledge and skills do not enable this, there is an urgent need for research to solve the problem.

It is very significant that, within the last few days the government has introduced measures to control the concentration of Radon in houses in the South-West where some serious health risks existed.

In principle there are several ways of approaching the problem of indoor air pollution control. They may be summarised.

Remove the source of pollution.

Provide local air extract at pollution sources.

Provide sufficient general ventilation to dilute and remove the pollution.

Purification of the internal air
(Masking has been used in the past but cannot be recommended as a method of solution)

None of these measures alone can solve the whole range of air pollution problems. Removal of the source of pollution can apply to unflued fixed appliances, but it cannot apply to occupants and does not seem practicable to apply to smoking or to furnishing foams. Local extract such as washing machines or cookers but cannot apply to moving occupants, chipboard floors or to oil heaters.

The provision of general ventilation is the most generally applicable of the possible control strategies. High ventilation rates are, however, incompatible with energy conservation and closely controlled ventilation is needed. It is difficult to achieve this.

In the present state of knowledge and skill in ventilation control, the realistic approach seems to be the one which has been adopted in the past, that of ensuring that adequate flows of air can reach the exterior of the building and to provide means of entry for air to the building itself under the control of the occupants. In summer, in the majority of buildings windows can be opened to give effective control of ventilation. Winter conditions present a different problem.

Traditionally buildings were far from air-tight. Flues and ventilators were often present and always in habitable domestic rooms. Windows did not seal tightly and there were other passages for air leakage. Natural air change rates when all windows and doors were closed could still be significant and in practice met the need for a minimum level of air change in winter conditions. In energy saving construction the minimum ventilation rate with doors and windows shut is likely to be very low and not adequate for winter ventilation. Most windows do not offer adequate control for winter use. The degree of opening of a large opening light cannot be controlled to give draught free ventilation at the levels appropriate for winter use.

A realistic approach to the problem, which has already been adopted in some countries, is to make the whole of the basic construction, including doors and windows, as airtight as possible and then to provide specific controllable features for winter ventilation.

Clearly the most predictable way to control low levels of ventilation is by mechanical means. In some countries where energy conservation is very important this method is already being adopted. It is said that 95% of new Swedish dwellings are built to be as tightly sealed as possible and are equipped with mechanical extract systems extracting through kitchens and bathrooms giving an overall ventilation rate of one half air change per hour.

Although this may be very effective solution in Sweden there are several reasons which prevent it being readily adopted as a solution in this country. Although temperatures here occasionally do drop to extremely low levels by any standard, such occasions are comparatively short lived and do not occur every year.

A more consistant level of cold in Sweden means opening windows in kitchens and bathrooms is not a feasible ventilation measure in winter, and building regulations require the provision of quite expensive means of permanent natural ventilation.

Thus there is a more acute situation recognised by the occupants and the cost of the natural ventilation provisions can be set against a large part of the cost of the mechanical ventilation system which requires much simpler exit provisions through the building fabric.

To ensure that the controlled low rate of ventilation is maintained, the background infiltration is minimised by very high standards of workmanship in scaling the building and also, if condensation with low rates of ventilation is to be avoided, in ensuring that no cold bridges will cause trouble. In addition, the amount of moisture present in the atmosphere at very low temperatures is much less than that at higher temperatures. In terms of condensation risk, therefore, the low temperatures represent an advantage.

FACTORS REDUCING VENTILATION RATES

1. Abandonment of requirement for flues or vents in habitable rooms.

2. More tightly sealed windows.

3. Lack of night ventilators in windows.

4. Dense airtight construction in some cases.

5. Weather stripping.

6. Security dictating that windows must be kept closed.

7. Flueless heating systems or balanced flues not drawing air from interior.

In the UK climate where typical temperatures hover just above freezing and the relative humidities are extremely high, it is by no means certain that the ventilation rates used successfully in Sweden would be adequate. The additional expense of full mechanical ventilation in the UK would be considerable designers could be less certain that they would function efficiently, the noise levels would give rise to complaint and, on the experience associated with mechanical systems installed to overcome aircraft noise, it is very possible that the fans would not be adequately maintained or repaired when necessary. In this country one must, therefore, look to the possibilities of providing natural means of controllable ventilation, perhaps operating in conjunction with simple extract fans.

Purification of the internal air is clearly very important means of achieving adequate standard since it overcomes the great difficulty associated with dilution by means of general ventilators which is loss of heat. It is the subject of the following paper by Mr Hall to be published in our next issue.

Conclusions

Air quality is a vital problem but one where uncertainty reigns.

There is clearly an urgent need for comprehensive research to establish the sources and acceptable levels for pollutants in air in buildings, standards of ventilation required to maintain satisfactory conditions and the design features required in buildings to provide these ventilation standards.

At present building designers face a difficult problem. For most buildings there are no statutory requirements for air quality or for rates of ventilation. The indirect regulations governing form and fenestration are helpful but do not, in themselves, guarantee satisfactory performance.

The problem cannot be ignored and, because of the conflicting requirements of energy conservation and health, cannot be solved by generous provision favouring any one or the other.

At present in this particular area, with the exception of a few building types designers must rely upon their own judgement. It is not necessarily a bad thing for a building design problem such as this to be resolved by professional judgement and skilled design to be carried out with a level of understanding and skill, progressively informed by research, which would obviate the need for legislation to correct inadequate building performance.

POLLUTANTS OF INDOOR AIR AND THEIR SOURCES

	SOURCE									
	Smoking	Combustion	Metabolic activity	Furnishings	Building materials	Aerosols	Soil	Moulds & static water	Equipment	External air
Odour			✓							
Particulates	✓	✓			✓		✓			
Moisture		✓							✓	
Mites				✓				✓		
Micro organisms and allergens			✓	✓				✓		✓
Radon					✓		✓			
Asbestos					✓				✓	
Man made fibres				✓	✓					
Carbon monoxide	✓	✓								
Methane							✓			
Hydrogen sulphide							✓			
Oxides of nitrogen	✓	✓								
Sulphur dioxide		✓								
Carbon dioxide		✓	✓							
Formaldehyde		✓		✓	✓					
Various chemicals including fluoro and hydro carbons, ammonia etc.				✓			✓			