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REGULATORY ASPECTS OF INDOOR AIR QUALITY - A UK VIEW

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In order to establish if there is a significant hazard to health from indoor air pollutants a regulatory agency needs to answer the questions: What is the nature of the pollution? What are the effects on public health? What are acceptable levels and how may the pollutants be controlled? Once the problem is identified two regulatory approaches can be adopted. These may be based on control of sources or control of air. Measures to control sources include prohibition, compositional and performance standards, and restrictions on use. Measures to control air include setting permitted or 'guideline' levels for pollutants or dilution of pollutants by ventilation. Specific indoor air quality issues that have arisen in the U.K in recent years have involved asbestos, formaldehyde, pesticide residues, radon and products of combustion. Of these, the use of asbestos in buildings has generated most public anxiety. Different measures have been taken with regard to each of these substances. In general an educational approach has been adopted, although national standards, industry-self regulation and some regulatory measures have been used. In the U.K control of ill defined, distributed or non stationary indoor air pollutants such as body odour, tobacco smoke and water vapour, is considered to be best achieved by suitable ventilation. Research is being undertaken on methods of measurement of natural ventilation rates of buildings using automated multiple tracer gas techniques. Computer based models for predicting natural ventilation and infiltration rates are being developed.

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Introduction

The climate of the United Kingdom is usually termed 'mild' but this winter (1985) there have been some extended periods of cold weather during which temperatures of -20 C were recorded. Certainly the UK climate is cold enough for homes and other buildings to be heated during a large part of the year and for heat (energy) conservation measures to be applied. These measures carry with them implications for indoor air quality (IAQ).

This paper will attempt to describe the issue of IAQ as perceived by the Department of the Environment in the United Kingdom and give an overview of some of the ways in which problems are being tackled.

Problems of indoor air quality

The first problem that confronts a regulatory agency, such as the Department of the Environment, is that of deciding whether there is a genuine hazard and a significant risk to the health and wellbeing of the public. The response in each case will differ. The response to an issue in which public perception exaggerates a problem may be largely educatory or advisory, whereas the response to a significant risk may require a number of actions to be taken which will be discussed later.

In order to decide on the appropriate response the following questions need to be answered:-

1. What is the nature of the pollution?

   - What is the pollutant, can it be identified?

   - Are single or multiple substances involved?

   - What concentrations are found/how reliable are the measurements?

   - Where does the pollution occur? Is it widespread or confined to a single location? Can sources be identified? In what kind of building does it occur (homes or public buildings, shops, factories, offices etc)? Is it associated with any particular type of construction?

2. What are the effects of the pollutants on public health?

   - How many people are exposed, or are likely to be exposed and for how long?

   - Have any relevant epidemiological studies been carried out?

   - Is there any information on health effects from animal studies?

3. What are 'acceptable' levels?

   - Is it possible to make an estimate of risk?

   - Have 'acceptable' levels been defined in other countries?

4. How may the pollutants be controlled?

   - Are there any precedents which may be followed? (ie for similar pollutants)

- Have control measures been adopted in other countries?

Answers to many of these questions will not be available and, whilst research may provide useful information in some instances, there may not always be sufficient time for a comprehensive investigation to be carried out. It may be that, particularly where there is considerable public anxiety, a 'quick and dirty' investigation, providing general indications of the appropriate response to the situation is all that is possible. This may be modified at a later date when more detailed studies have been completed. It is often the case, however, that decisions are required in a compressed timescale, with incomplete information on the finer detail.

Policy strategies

Having identified a problem, two fundamental approaches can be chosen, either singly or in combination, they are not mutually exclusive. These are (a) control of sources and (b) control of air.

Measures to control sources may take the form of prohibition or setting compositional standards for materials which contain the pollutant, setting performance standards for example by specifying maximum emission rates of the pollutant from the material under specified conditions, or control of use of the material, for example by codes of good practice. Measures to control the air may involve setting maximum allowable levels of specific pollutants or recommending guideline concentrations. Alternatively, control may rely on dilution of pollutants by ventilation.

There are problems with all of these approaches, for example, both industry and the public are likely to protest at the complete banning of popular products. It may not be technically feasible to either eliminate or reduce the proportion of a pollutant in a product. It is possible that the pollutant may also be an essential component, for which no substitute is available. Specification of emission rates depends upon the availability of suitable methods for measuring them. Both compositional and performance standards must also be shown to relate to airborne levels of the pollutant and exposure of individuals.

Control of the way in which a product containing a pollutant is used may be particularly difficult. This may be done by restricting supply (ie a partial ban) or by limiting use to specified or trained users, and specifying methods and procedures for utilisation. Such controls are likely to be inoperable for common, 'domestic' products in widespread use, for example polishes, paints and adhesives.

Similarly, 'control of air' by specification of maximum permissible levels of pollutants depends upon suitable measuring techniques being available, and on the feasibility of estimating an acceptable risk to health of the public from inhalation of the pollutant. Control by regulation of ventilation must be reconciled with energy conservation measures.

The examples of regulatory difficulties cited are merely illustrative, they are not intended to be an exhaustive list. Furthermore, any control measures taken, or regulations made will need to be enforced, which in itself may not be straightforward.

Specific indoor air quality issues in the United Kingdom

Specific indoor air quality issues which have arisen in the UK in recent years illustrate the application of different strategies. Concern has been expressed over asbestos, formaldehyde, pesticide residues, radon and products of combustion in the indoor environment. Of these, it is undoubtedly the use of asbestos in buildings that has generated most public anxiety.

(i) Asbestos

Whereas exposure to high levels of airborne asbestos fibre in the work-place has in the past given rise to an unacceptable risk to health, and many fatalities from asbestos related disease have occurred, exposure to the very low levels of fibres measures in buildings has been estimated in the UK (1), USA (2), Canada (3) and the Federal Republic of Germany (4) to give rise to a very low lifetime risk of premature death, comparable to the risk of being struck by lightning in the UK. Nevertheless, public perception of the risk is entirely different.

The UK Government has taken extensive action to control workplace exposure. Comprehensive regulations are either in place, or are being introduced to control work practices, limit airborne fibre levels and to restrict work with certain types of asbestos to trained personnel. Action on asbestos in buildings has been on two broad fronts, the provision of advice, supported by a programme of monitoring and action to control sources of emission. The advice element consists of two publications, one a booklet (5) entitled - 'Asbestos Materials in Buildings' - directed at engineers, architects, health officers and those responsible for building maintenance, operation and design, and also available for public purchase, and secondly a free leaflet (6) giving detailed advice to householders, over 300,000 copies of which have now been distributed to homes in the UK.

The monitoring element consists of a programme of measurements of air-borne asbestos fibre concentrations made using electron microscopy, in buildings known to contain asbestos, in urban and rural environments, in the neighbourhood of factories making asbestos products, and near waste disposal sites where asbestos materials may have been dumped. The results of the monitoring programme obtained to date have been published (7, 8) and have been used in the preparation of the publications described above. The ability to monitor is limited by the expense and difficulty of the techniques available.

On the second front, control of sources of emission has been mainly by control of use. Actions taken or to be introduced shortly include banning of the spraying of asbestos, and of all use of crocidolite and amosite. The use of chrysotile is still permitted but all products containing it will have to be labelled in the near future. Manufacturers have voluntarily ceased producing asbestos insulating board and textured plasters containing asbestos thereby controlling supply and eliminating sources. The use of substitute materials where appropriate, is encouraged.

(ii) Formaldehyde:

There has been considerable public anxiety in the UK over recent years concerning the health effect of formaldehyde in homes. Most concern has been expressed over the release of formaldehyde into indoor environments following insulation of homes with urea formaldehyde foam insulation (UFFI). The climate in the UK is certainly cold enough to warrant this form of insulation, and over 1.25 million homes have been insulated with foam. Householders in a very small proportion of these homes have reported adverse health effects following insulation of their homes.

The release of formaldehyde from wood products, carpets and other domestic sources is not, however, widely perceived to be a problem.

The UK Government response in this case has been to mount an extensive investigation of levels of formaldehyde in 120 homes and 58 buildings of other types, both with and without UFFI. The Department of the Environment Building Research establishment found that levels in uninsulated homes were 0.047 ppm (mean) and in homes insulated with UFFI 0.093 ppm (mean) (9). However in houses of pre-fabricated concrete construction much higher levels of 1.62 ppm (mean), following foam installations (and dropping to 0.42 ppm after a year) were measured. Levels of formaldehyde vapour in houses of conventional construction have been measured in the UK, USA and Canada and found to be broadly comparable.

It was clear that the highest formaldehyde levels were associated with inappropriate installation. The strategy employed in this case has been essentially one of control of use. The relevant British Standard (10a) which specifies the formulation of the foam and the Code of Practice (10b) for insulating houses have been revised to ensure that companies installing foam insulation have proper expertise, that operatives are suitably trained, and that the foam itself is properly formulated. A survey of a building prior to installation of foam is required to check that it is suitable for insulation in this way (ie that the inner masonry leaf is intact, or that the building is of suitable construction). The standards are enforced by the British Standards Institute by inspection of records of test and of complaints. Further control of installation is implemented by the trade associations (the National Cavity Insulation Association and the Cavity Foam Bureau) which require their members to work in accordance with British Standards. The manufacturers of foaming agents have refused to supply installers who are not members of the Trade Association or who do not comply with the relevant British Standards. Control is, therefore, essentially by industry self-regulation, and current experience has shown this to be satisfactory.

The Building Research establishment is also mounting a research programme examining formaldehyde releases from other sources in homes (wood products, paints, resins etc).

(iii) Dieldrin

The use of dieldrin in timber treatments to control wood boring insects (and also in carpets as an insecticide) has been shown, in some circumstances, to give rise to persistent, elevated concentrations of the pesticide in indoor environments (11). A control of source by control of use strategy has been adopted. Manufacturers and timber treatment companies have voluntarily agreed to cease using the pesticide in their products, and a similar voluntary ban on the use of dieldrin as an insecticide in carpets has been instituted. Legislation now being considered will put these voluntary bans on a statutory basis.

(iv) Radon

The risk to public health from radon and its progeny in the indoor environment in the UK is being investigated by the National Radiological Protection Board which is undertaking a number of regional surveys as well as a national postal survey, using track etch detectors, of some 2000 dwellings (12, 13). Preliminary results indicate that the national average dose resulting from exposure to radon and its daughters in homes is low, approximately 0.8 mSv/year. However in some areas of the country, particularly where the geological structure is mostly igneous, the measured levels indicate substantially higher average exposures (3-6 mSv/year). In some individual dwellings levels may be up to two orders of magnitude higher than the national average level.

Detailed field and laboratory measurements have shown that building materials are not a major source of radon in UK housing. The major contributor, particularly in houses with the higher levels, is the sub-soil beneath the building. Current work, being undertaken in conjunction with the Building Research Establishment, is aimed at investigating appropriate remedial measures for high radon houses. Controls options are limited by the nature and origins of the pollutant although source control rather than air control is indicated by current research.

(v) Combustion products

The prime concern is with carbon monoxide, resulting either from mal-operation of flued combustion appliances or from unflued heaters and cooking ranges. This is currently dealt with in two ways. National Building Regulations require adequate air supply for combustion appliances. This is designed to ensure that flues operate effectively and, in the case of unflued appliances, that the combustion products are sufficiently diluted to prevent the air entering the burners from becoming vitiated and, hence, causing incomplete combustion with related high carbon monoxide production rates. Statutory Regulations are further supported by Codes of Practice giving detailed requirements for a variety of appliance types as well as by advice available from the relevant field authorities. In addition, the amount of carbon monoxide produced by the burners under normal operation is covered, in many cases by self-regulation, through the fuel authorities, who, in granting type approval, require a limiting CO/CO_2 ratio in the combustion products.

Ventilation as a control option

In this context ventilation is taken to mean the dilution of any airborne pollutant to an appropriate concentration. This may be achieved using notionally pollutant-free outdoor air or by using recirculated air which has been cleaned, generally by filtration. However if the pollutant source is well-defined then local extract ventilation, in which the airborne pollutant is removed before it can mix with the general body of air within the building, may be a more appropriate solution. Sufficient make-up air must be supplied in order to ensure that the extract system operates effectively.

Ventilation is most appropriate as a means of controlling common pollutants, particularly where the sources are ill-defined, distributed or non-stationary. The obvious pollutants are those related to occupancy (body odour, products of respiration and tobacco smoking) or to activities or processes within a building (combustion products, water vapour from domestic tasks).

As noted earlier, the choice of method for indoor air pollution control in any given situation is governed by a number of factors, not least the cost and practicablility of implementation. For ventilation with outside air in cold climates, costs are mainly associated with the energy required to raise the air to indoor temperature. These factors place an upper limit on air supply requirements. Ventilation requirements should, therefore, be based upon generally expected source strengths. If this leads to high fresh air supply rates, then other methods, such as source control, will be more appropriate. The same applies to situations where source strengths are substantially higher than generally expected (eg. houses with high radon levels).

On present evidence, allowing for special measures in atypical situations, adequate indoor air quality will generally be achieved in UK houses provided enough air is supplied to control water vapour, and hence condensation and mould growth, and to ensure the safe operation of combustion appliances.

Ventilation prediction and measurement

A standard is of very little use if compliance cannot be checked. Ventilation standards require either direct measurement of air exchange rates or an indirect measurement, say of open area or other building characteristic from which natural ventilation rate can be inferred. In principle any system incorporating mechanical ventilation should allow the air supply rate to be measured readily, although experience indicates that this is rarely repeated after initial commissioning.

In naturally ventilated buildings direct measurement of the air supply rate is much more difficult, requiring the use of tracer gas techniques. In addition, by its very nature, natural ventilation is dependent upon wind speed, wind direction and the difference between internal and external temperature and is, hence, highly variable, although less so in very cold climates in which stack effect will dominate for a higher proportion of the time than in milder climates. In practice the only satisfactory method of regulation is to specify required areas and, possibly also, locations of permanent and controllable openings. Compliance can then be readily ascertained. In order to provide a better understanding of natural ventilation and consequently to provide a basis for specifying standards in this form, the Department of the Environment supports research at its own laboratories at the Building Research Establishment and under contract elsewhere.

This work includes the development of computer-based models for predicting natural ventilation and infiltration rates. The simplest of these is concerned only with air exchange across the building envelope, and is primarily designed for dwellings and simple commercial and industrial buildings. Initially developed to enable infiltration performance to be predicted from whole building air leakage measurements (14), made using 'blower door' type equipment, this 'single cell' model has been extended to include specific types of air flow path including heated and unheated flues, open windows, ducts and simple mechanical ventilation systems. Taken with appropriate meteorological statistics, this model enables the dimensions of permanent, or controllable, openings to be calculated to satisfy given fresh air requirements for a chosen proportion of time. A more complex multi-cell model has been developed for application to larger and more complex buildings.

The models require input data concerning background leakage through the structure and surface pressure coefficients. The latter are being obtained, for houses and low-rise buildings, from a series of parametric wind tunnel studies. Air leakage characteristics of houses are being obtained from the results of blower door surveys, designed to cover a typical range of UK housing stock.

In order both to validate these models, and to increase the stock of knowledge of ventilation rates in practice, tracer gas methods are used. Initially classical decay rate techniques employing a single tracer gas were used to obtain whole house infiltration and natural ventilation rates (15). More recently the emphasis has been on the development of strategies for making measurements of natural ventilation rate in buildings larger and more complex than dwellings (16, 17). In addition to investigating simple techniques for measuring overall ventilation rates, more complex, automated methods, in some cases involving the use of several tracer gases, have been developed (18, 19), in order to investigate the natural ventilation rate of individual zones or rooms within a building as well as the interchange between such zones.

Although the techniques described above have been primarily developed in the context of natural ventilation, they can be applied, in particular in the context of indoor air pollution, to the movement of air in mechanically ventilated buildings. Information from multiple tracer experiments can be applied in conjunction with pollutant dispersion models and a knowledge of strength and location of sources to calculate the time-varying concentration of a pollutant within a building. The automated sampling equipment has also been used for preliminary field measurements of the effectiveness of air distribution and pollutant control by mechanical ventilation systems, based upon the ideas of Sandberg (2) and Skaret (21).

Conclusion

There is no single regulatory measure which by itself can assure satisfactory air quality in all indoor environments. A range of policy options are available. Thus, where a definite cause of unsatisfactory indoor air quality can be identified appropriate policies to control it can be adopted. These may be legislative but in some circumstances satisfactory air quality may be assured by voluntary measures. With regard to non-specific indoor air pollutants, it is the current UK view that satisfactory indoor air quality can be best assured by ventilation. The technical difficulties of this approach are recognised; ventilation is not simply a matter of opening a window. In cold climates energy conservation measures must be well to the fore.

The views expressed in this paper are those of the Authors alone and do not necessarily represent those of the Department of the Environment.

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