FOR MEMBERS' USE ONLY **COMEAP/2001/10**

COMMITTEE ON THE MEDICAL EFFECTS OF AIR POLLUTANTS

INDOOR AIR QUALITY: DEVELOPMENT OF GUIDANCE

1. During the past ten years Members of COMEAP have focused their attention on outdoor air pollution rather than on indoor air pollution. Attention has been paid to certain pollutants such as nitrogen dioxide and carbon monoxide which are significant problems both indoors and out.

2. Because people spend more than 80% of their lives indoors the majority of exposure to most air pollutants occurs indoors. Pollutants such as particles may be generated outdoors and penetrate indoors; nitrogen dioxide and carbon monoxide are produced both indoors and out. Ozone is largely produced by photochemical reactions taking place outdoors, though photocopiers and printers may produce significant amounts indoors. For some volatile organic compounds, including organic solvents and aldehydes, indoor sources may predominate.

3. A strategy for improving air quality was developed by DETR and DH some years ago. This strategy was based on:

(i) research into indoor air quality;

(ii) the provision of information and advice to the public via, for example, pamphlets;

(iii) the UK Building Regulations.

The development of guidelines for indoor air quality was considered but it was felt that producing such guidelines would not significantly assist the strategy.

4. The development of guidelines for indoor air quality presents several problems. These include their relationship with extant guidelines and standards for outdoor air quality and the possibility that indoor air quality might be misinterpreted as standards requiring monitoring and enforcement. This would be neither feasible nor desirable.

5. Staff in DETR and DH are currently reviewing the idea that further guidance on indoor air quality might be developed. Such guidance might include guidelines but would also include further advice on how indoor air quality might be improved.

6. As a first step in this process the attached paper discusses the case for indoor air quality guidelines. The paper builds on work undertaken at the MRC Institute for Environment and Health by the Institute's Acting Director, Dr Paul Harrison.

7. Members are invited to give their views on:

(i) the case for developing further guidance on indoor air quality;

(ii) the case for developing guidelines on indoor air quality;

(iii) the approaches to developing guidelines set out in the attached paper on a pollutant by pollutant basis.

Secretariat
June 2001

INDOOR AIR POLLUTION: DISCUSSION AND PROPOSALS FOR THE USE AND SETTING OF INDOOR AIR QUALITY GUIDELINES FOR THE UK

R L Maynard Department of Health, November 2000

Introduction

1. A number of exhaustive reviews of indoor air quality are available.[1-3] Some of these focus on the UK,[3] others take a more international approach.[1,2] This paper does not seek to report work covered in these major reviews. Attention is drawn to gaps in knowledge and to the problems in the indoor air field that are likely to be raised during the coming decade or so. Where possible, attention has been focused on implications for building standards and regulations. The case for guidelines is considered and guidelines are suggested.

2. A great deal is known about the possible effects on health of the common air pollutants encountered indoors. This is unsurprising as these are, in general, the same pollutants as are encountered outdoors and in occupational settings. Despite this, little is known of the actual effects of indoor air pollutants on health. Concentrations of particles and nitrogen dioxide may be significantly greater indoors than out and yet there is little direct evidence to suggest that exposure to such pollutants indoors affects health. There are exceptions to this: carbon monoxide consultations may rise to lethal levels indoors, this is not the case outdoors.

3. The main reason for the lack of evidence of effects of indoor exposure to common air pollutants is that the epidemiological methods which have recently revealed associations between current outdoor concentrations of pollutants and health outcomes cannot be applied to indoor exposures. This requires a little explanation. Beginning in about 1990, a rapidly increasing number of epidemiological studies using time-series techniques have shown statistically significant associations between concentrations of pollutants generally monitored at a single outdoor site in a town or city and the daily count of a wide range of indicators of ill-health. These include daily deaths from non-accidental causes and admissions to hospital for treatment of respiratory and cardiovascular diseases. Indices of less serious effects on health, including GP consultations, symptoms and consumption of anti-asthma therapies have also been found by some workers to be associated with daily concentrations of pollutants. These studies depend on a satisfactory accounting for the effects of confounding factors including temperature, season and epidemics of infectious disease. A detailed account of these studies as regards particles may be found in the COMEAP report on Non-Biological Particles and Health.[4] Much effort has been spent in trying to decide whether the observed associations are causal: the general, but not universal, view is that the associations are causal.[5,6] For the purposes of this paper it will be accepted that significant associations with mass concentrations of particles (measured as PM_{10} or $PM_{2.5}$ - the mass per m^3 of particles generally less than 10 and 2.5 µm aerodynamic diameter, respectively) and nitrogen dioxide have been observed. It is accepted that the evidence linking nitrogen dioxide with effects on health is a little less well developed than that with regard to particles. Associations with concentrations of carbon monoxide have been less extensively studied; associations with concentrations of sulphur dioxide (SO_2) are less easy to interpret as SO_2 have

been reported but may be acting as a surrogate for secondary particles, ie for a sulphate, aerosol. I shall consider only particles and nitrogen dioxide here. Consider NO_2. Let us assume:

(i) that the indoor and outdoor concentrations vary together: the outdoor driving the indoor;

(ii) that a given exposure to NO_2 outdoors has the same effects as a similar exposure indoors.

Of these, (i) is capable of being explored by appropriate measurements. (ii) This sounds inevitably true but is actually rather complicated. Let us imagine that the body's response to NO_2 is dependent not only on the total exposure measured as $mg.m^{-3}.d$ or $\mu g.m^{-3}.hr$ but on a more complex product of concentration and time. Experimental studies have shown that the response to NO_2 is dependent not only on the concentration.time product but also on the peak concentration.[7] This can be expressed as:

$$\text{Response} = k\, c^{k'}.t$$

Where c = concentration, t = time and k and k' are constants. Thus exposure to 100 $\mu g.m^{-3}$ for 10 hours may not produce the same response as exposure to 10,000 $\mu g.m^{-3}$ for 0.1 hours. Given that we know that indoor concentrations of NO_2, at least in homes with gas cookers, are characterised by peaks far in excess of the 24 hour average concentration, we should be careful about saying that the response to exposure to *x* $\mu g.m^{-3}.hrs$ indoors is equivalent to that to *x* $\mu g.m^{-3}.hr$ outdoors.

4. Where does this leave us? In our usual interpretation of the results of time-series studies dealing with NO_2 we tend to assume that the outdoor concentration of NO_2 reflects in a consistent way the daily exposure to NO_2. We express the relationship in terms of this surrogate of exposure:

> eg, 10 $\mu g.m^{-3}$ increase in 24 hour average outdoor concentration of NO_2 is associated with a 0.5% increase in daily deaths.

We should be cautious in interpreting this statement. An extreme case makes this clear. Imagine that nobody went outdoors at all and that the relationship above still held. Without knowing the details of assumption 3(i) we would be able to say very little about the actual relationship between exposure to NO_2 and effects on health. My conclusion is that time-series studies as usually conducted and interpreted tell us little about the real relationship between exposure to NO_2 and effects on health and little about the association between indoor concentrations of NO_2 and effects on health. This rather gloomy conclusion may be surprising as the results of time-series studies have been quoted to support the assertion that exposure to air pollutants indoors have an impact on health.[8]

5. If the problem of predicting the effects on health of indoor exposure to NO_2 from the results of time-series studies is difficult, predicting the effects of indoor exposure to particles is more difficult. Unlike NO_2, "particles" are not one chemical substance but a complex mixture. Though any aerosol can be described in terms of a

size-limited mass concentration it would be unwise to believe that exposure to a sodium chloride aerosol (PM_{10} = 100 µg.m^{-3}) would have the same effects on exposure to a zinc oxide aerosol (PM_{10} = 100 µg.m^{-3}). The indoor aerosol is by no means identical with the outdoor aerosol though the outdoor aerosol does influence that indoors. We know, for example, that indoor $PM_{2.5}$ levels are about 60% of those outdoors. Indoor activities such as smoking, cleaning and moving about on carpeted surfaces produces an aerosol. The particles generated vary in size and composition and, possibly, in their biological effects. Gas cooking leads to the production of high concentrations (expressed in numerical rather than mass terms) of very small particles.[9] The effect of exposure to such particles is unknown though it has been suggested that in outdoor air ultrafine particles (< 100 nm diameter) play a role in producing the effects reflected in the reported associations between PM_{10} and daily health-related events discussed above.[10,11] Even here the problem is more complicated that it may appear at first sight in that it is known that not all ultrafine particles are equi-toxic.[12,13]

6. These difficulties in applying the findings of time-series studies to the indoor environment will be difficult to resolve. The great advantage of time-series studies lies in their power to detect small effects. This power is due to the large populations that can be studied. For example, a study in London will look at a population of 8 million. It is difficult to imagine any other form of study, save an ecological comparison between cities, that could involve such a large number of people. It may perhaps be correct to say that time-series studies sacrifice general applicability of their findings for their great power to detect small effects. The unit of analysis in time-series studies is the day: the studies tell us about the effects of different days - the difference between the days being reflected by the daily concentrations of pollutants.[14] Time-series studies do not tell us about individuals.

7. Studies that do tell us about individuals, for example, panel studies and studies of the exposure of individuals to known concentrations of air pollutants, have not consistently found effects at pollutant concentrations that are associated with effects in time-series studies.[15] This has been seen, by some, as a point for the case against accepting the findings of the time-series studies.[6] This interpretation may be false. We should recall:

(i) the great power of time-series studies to detect small effects;

(ii) that experimental exposures cannot embrace the full range of individual sensitivities likely to occur in a population;

(iii) that in any population there will be a distribution of exposure and it is possible that the people responding to an air pollutant may be responding to a concentration in excess of that recorded at a monitoring station. This is an important point and may explain the "failure" of time-series studies to detect a threshold concentration below which there are no effects on health.

8. It is clear from the above that we are not well placed to use time-series studies to predict the effects of exposure to indoor concentrations of nitrogen dioxide and particles. There may be effects at current indoor levels but we cannot say how large

and therefore how important, these effects are. Nor can we easily predict the benefits to health that might accrue if indoor levels were reduced.

9. The position regarding carbon monoxide is more encouraging. There is clear evidence that indoor exposure to high levels of CO causes deaths and serious intoxication.[16] It has been suggested that long-term exposure to lower and apparently non-toxic concentration can also produce effects though the evidence for this is much less clear.[17] Recent studies have shown that exposure to concentrations of CO that produce low levels of carboxyhaemoglobin in the blood can affect people with an already impaired blood supply to the heart.[18] These findings have led to a re-consideration of so-called "safe" levels of exposure to CO.

10. Considerable attention has been paid to indoor exposure to organic compounds.[1] Some cause annoyance as a result of odour and irritation: for example, formaldehyde whilst, others, such as benzene, are known human carcinogens. For compounds such as benzene no absolutely safe level of exposure can be set. This is because such compounds act by damaging the genetic material of cells and no safe level of damage can be agreed. It can be agreed, however, that very low levels of exposure will be likely to be associated with very small risks. Describing these risks in numerical terms has proved difficult and though WHO and other organisations such as the US EPA do so, the DH Committee on Carcinogenicity of Chemicals in Food, Consumer Products and the Environment (COC) does not support this approach.[19] The approach adopted in the UK is based on the principle that exposure should be reduced as far as possible. As a guide to practice in regulating outdoor air pollutants the DETR Expert Panel on Air Quality Standards (EPAQS) has set standards for benzene and other organic carcinogens (PAH compounds and 1,3-butadiene).[20-22] Exposure to levels specified by these standards is likely to be associated with an exceedingly small risk to health.

11. Irritant compounds such as formaldehyde sometimes produce effects at indoor concentrations.[3] This is the case when particular sources of aldehydes exist in the indoor environment. Sources of aldehydes exist in the indoor environment. These include pressed wood products bonded with urea formaldehyde resin, new laid carpets and some types of cavity wall insulation. It has been suggested that outdoor exposure to aldehydes contribute to the complaints of eye irritation in urban areas. The evidence for this is not completely convincing: particles contained in fresh diesel exhaust are perhaps as likely to be the active component of the urban air pollution mixtures.

New Problems and Possible Solutions

12. Buildings in the UK are an important source of carbon dioxide: the most important "greenhouse gas". In order to meet planned reductions in CO_2 emissions less heating of buildings will be essential and to achieve this, without jeopardising indoor temperatures, tighter buildings may well be needed. Ventilation will remain important if damp, condensation and fungal growth are to be controlled: in larger buildings air cleaning and recirculation of air with heat recovery may be needed.

These measures may well lead to an increase in indoor concentrations of air pollutants. Guidance on acceptable levels of indoor air pollutants would be valuable to architects and construction engineers designing new buildings. It may also be useful for such guidance to be incorporated in building regulations. Guidelines may also be useful in developing emission standards and product labelling for indoor sources of pollutants.

13. The case for guidelines for indoor air quality is clearly explained by Dr Paul Harrison (Acting Director MRC Institute for Environment and Health) in Appendix 1 of a survey that was produced as part of a DH initiative on indoor air pollution launched at a symposium at IEH in October 1999. A report on the symposium is available from IEH.[8] Dr Harrison's paper is attached at Annex A.

14. It will be seen that Dr Harrison ended his paper with a list of questions. I have tried to answer these below. The answers provided require discussion with and refinement by the building community and are put forward as a stimulus to such discussion.

Dr Harrison's Questions: My Answers

15. (i) What form should the guidelines take and where should they apply?

The guidelines should take the form of recommended concentrations for air pollutants - each concentration being qualified by an averaging time and coupled with advice on how concentrations should be measured. The guidelines should apply to any non-occupational indoor environment. Occupational environments are dealt with by HSE. The guidelines are intended to aid in the development of Building Regulations. The guidelines need not themselves appear in the regulations: it may be that appropriate regulations should be framed to ensure a high probability of the guidelines being met. The guidelines could also play a role in allowing assessment of indoor concentrations of air pollutants in existing buildings including, for example, schools and hospitals. Having something with which to compare measured levels would be a significant step forward.

(ii) What are the priority pollutants for guideline setting?

It would be possible to make a case for setting guidelines for a large range of pollutants. It is suggested that only the following are focused upon:

nitrogen dioxide;

carbon monoxide;

formaldehyde;

PAH compounds;

benzene.

For each of the above indoor exposure contributes a large proportion of total exposure. Particles present a special problem. This has been touched on above. My view is that we do not, as yet, know enough about the effects of indoor exposure to particles to begin to set a guideline.

(iii) Could or should existing guideline levels (eg, WHO, EPAQS) be used "off the shelf"?

For benzene and PAH compounds I believe this would be satisfactory. Effects at plausible indoor concentrations are limited to cancer and long-term averaging times are appropriate to controlling exposure to prevent or reduce such effects. If this is accepted then a guideline for benzene of 5 ppb (annual average concentration) and for PAH compounds (using benzo[a]pyrene (BaP) as an indicator compound) of 0.25 ng/m^3 (annual average concentration), as recommended for outdoor conditions by EPAQS could be adopted. The arguments in favour of using BaP as an indicator compound are explained in the EPAQS report on PAH compounds.[21] In the case of formaldehyde the great majority of the evidence of effects upon which a guideline could be based comes from studies of the effects of indoor exposures. The WHO Air Quality Guideline of 0.1 mg/m^3 (as a 30 minute average), which was based on this evidence, could therefore be adopted.[23] This guideline was specifically intended to protect against nose and eye irritation though it was accepted that some people could sense the presence of formaldehyde at still lower concentrations. Though formaldehyde is accepted as a carcinogen (it can produce cancer of the nasal epithelium) the WHO Guideline is 10-fold below the level needed to produce epithelial damage. It is unlikely that there is a risk of cancer at such a low level of exposure. Carbon monoxide acts by competing, very effectively, with oxygen for binding to haemoglobin. In addition, its binding to haemoglobin displaces the dissociation curve of oxyhaemoglobin to the left and thus oxygen is given up less readily at the tissues. This adds to the effects of the reduced overall capacity to transport oxygen. The uptake of CO by haemoglobin is slow at the concentrations likely to be encountered.[24] Equilibrium concentrations are predictable and the figure shown in Annex 2 illustrates both the equilibrium concentration and the rate of uptake of CO at different levels of ventilation. WHO used data similar to that shown in the figure to produce the following guidelines:

15-minute averaging time:	90 ppm (100 mg/m^3);
30-minute averaging time:	50 ppm (60 mg/m^3);
1-hour averaging time:	25 ppm (30 $\mu g/m^3$);
8-hour averaging time:	10 ppm (10 $\mu g/m^3$).

These figures could be safely adopted as guidelines for indoor levels of carbon monoxide.

For nitrogen dioxide the picture is much less clear. The case against using data derived from time-series studies is discussed above. If this is accepted then such evidence as is available from experimental exposures and point studies must be used to set an indoor air quality guideline. It is fortunate that WHO adopted this approach in setting an Air Quality Guideline for NO_2. The following paragraph is taken from the latest WHO Air Quality Guidelines for Europe:[23]

Guidelines

> Despite the large number of acute human controlled exposure studies several which used multiple concentrations, there is no evidence for a clearly defined concentration response relationship for NO_2 exposure. For acute exposures, only very high concentrations (>1,000 ppb, 1,900 µg/m^3) affect health people. Asthmatics and patients with chronic obstructive pulmonary disease are clearly more susceptible for acute changes in lung function, airway responsiveness, and symptoms. Based on small changes in lung function (<5% drop in FEV_1 between air and NO_2 exposure) and changes in airway responsiveness in several studies, a range of 0.20 to 0.30 ppm (375 to 565 µg/m^3) is a clear lowest observed effect level. A 50% margin of safety is proposed because of the reported statistically significant increase in response to a bronchoconstrictor (ie, increased airway responsiveness) with exposure to 190 µg/m^3 and a meta analysis suggesting changes in airway responsiveness below 365 µg/m^3 (200 ppb). (The significance of the response at 190 µg/m^3 [100 ppb] has been questioned on the basis of an inappropriate statistical analysis.) Based on these human clinical data, a 1-h guideline of 200 µg/m^3 (100 ppb) is proposed. At double this recommended guideline (400 µg/m^3, 200 ppb), there is evidence to suggest possible small effects in pulmonary function of asthmatics. Should the asthmatic be exposed either simultaneously or sequentially to NO_2 and an aeroallergen, the risk of an exaggerated response to the allergen is increased. At 50% of the suggested guideline (ie, about 100 µg/m^3, 50 ppb), there have been no studies of acute response in 1 h.
>
> Although there is no particular study or set of studies that clearly support selection of *a* specific value *for an annual average guideline,* the database nevertheless indicates a need to protect the public from chronic NO_2 exposures. For example, indoor air studies with a strong NO_2 source (eg, gas stoves) suggest than an increment of about 30 µg/m^3 (0.015 ppm), (2-week average) is associated with a 20% increase in lower respiratory illness in children 5 to 12 years of age. However, the affected children had a pattern of indoor exposure that included peak exposures higher than those typically encountered outdoors. Thus, they cannot be readily extrapolated quantitatively to the outdoor situation. Outdoor epidemiological studies have found qualitative evidence of ambient NO_2 exposures being associated with increased respiratory symptoms and lung function decreases in children (most clearly suggestive at annual average NO_2 concentrations of 50-70 µg/m^3 or higher and consistent with findings from indoor studies), although they do not provide clear exposure-response information for NO_2. *In these epidemiological studies, NO_2 has appeared to be a good indicator of the pollutant mixture.* Furthermore, animal toxicological studies show that prolonged exposures can cause decreases in lung host defence and changes in lung structure. *On these grounds, it is proposed that a long-term guideline for NO_2 be established. Selecting a well supported value based on the studies reviewed has not been possible, but it has been noted that a prior review conducted for the IPCS EHC document on NO_2 recommended an annual value of 40 µg/m^3 (0.021 ppm). In the absence of support for an alternative value, this figure is recognized as an air quality guideline.*

It will be seen that a guideline of 100 ppb (1 hour averaging time) was recommended. When EPAQS looked at essentially the same data they concluded that a concentration of 150 ppb (again, 1 hour averaging time) was appropriate.[25] Both values represent concentrations at which the risk of even mild effects is slight. For consistency within the UK the figure of 150 ppb (1 hour averaging time) might be adopted for use as an indoor air quality guideline. In considering a guideline based on a longer averaging time WHO turned to epidemiological data. It was noted that studies of indoor exposures had shown that children exposed to the raised levels of NO_2 found in homes with gas cookers (producing a 30 µg/m^3, 15 ppb increment in the 14 day average concentration of NO_2) experienced a 20% increase in lower respiratory illness. The WHO Expert Group noted that such children were likely to have been exposed to significantly higher peak levels of NO_2 than would be expected outdoors and thus declined to use these data to derive an outdoor Air Quality Guideline. The data could, however, be considered for use in setting an indoor guideline. This is not straightforward as there is little indication of an exposure response relationship: there being essentially just two groups of homes: with and without gas cookers. The WHO group also noted epidemiological studies that showed that long term exposure to concentrations of NO_2 of 50-75 µg/m^3 or higher (annual average concentrations) were associated with increased respiratory symptoms and decrements in indices of lung function in children.[26] These findings were felt to be consistent with the findings of the indoor studies. Deriving a long-term (annual) guideline from such data proved difficult and a figure of 40 µg/m^3 (20 ppb) was recognised though this was not supported by all the expert group. It is certainly a cautious guideline but has been adopted in the EC.[27] The guidelines of 150 ppb (1 hour average) and 20 ppb (annual average) could be adopted as indoor air quality guidelines. It should be noted that exceedance of both the guidelines for CO and NO_2 are likely in kitchens in which gas cookers are in use. The implications of this will need further consideration.

This leaves the problem of particles. Here the difficulties are large and it is difficult to think of how to set a guideline for indoor air that would have any validity. WHO found it difficult to do so for outdoor air and recommended instead of a guideline *per se* a concentration-response coefficient based on time-series studies.[23] No threshold of effect was assumed. EPAQS[28] adopted a different approach and, using data from a study in Birmingham, UK, recommended that a 24-hour running average concentration of PM_{10} of 50 µg/m^3 would be associated with only a small effect on health. Adoption of this figure for use indoors seems inappropriate given the points made above regarding time-series studies. It is suggested that for the moment no indoor guideline for particles be set.

(iv) What can be learned from similar initiatives elsewhere

Dr Harrison has provided tables of indoor air quality guidelines set by Canada, Germany, Norway and Poland. These are collated in Annex C. It will be seen that though there are differences between the values recommended by WHO, EPAQS (with regard to outdoor air pollutants) and the four countries listed, with regard to indoor conditions, the values suggested in the paragraphs above do not differ greatly from those used elsewhere. This offers some support for the use of these figures: at least as guidelines.

(v) How should sensitive or "at risk" groups be addressed?

The guidelines suggested above incorporate margins of safety that should protect such groups. This is explicitly stated in the derivation of the WHO Air Quality Guidelines and in the EPAQS recommendations.

(vi) What is the best approach to ensure appropriate and accurate measurements?

This question focuses on checking for compliance with guidelines. This is a difficult area and more detailed consideration of the use of guidelines in this way is needed. A useful first step would be to use the guidelines for planning purposes only. This would allow architects and construction engineers to plan for ventilation needs and for the removal of pollutants from sources that if left unchecked would lead to the guidelines being exceeded. Use of the guidelines in this limited way avoids the need for discussion of monitoring.

(vii) What more (if anything) need to be known before guidelines can be set?

The lack of hard data on the effects of indoor air pollutants on health has been stressed. Further research is needed to clarify these effects. This does not, however, mean that a first attempt to set guidelines for a limited range of compounds and for use limited to planning cannot be made now. Needs for research as set out in the IEH report "Indoor Air Quality in the Home".[3]

(viii) What problems might results from setting indoor air quality guidelines?

It may be found that many dwellings in the UK are unlikely to meet the guidelines suggested above. This is hardly a good reason for abandoning the idea of setting guidelines. On the contrary, if this is the case, efforts should be made to modify properties so that the guidelines are met. It may be that sectors of industry eg, the Gas Industry, may complain that the guidelines will place undue pressure on their products. This charge should be met by asking whether the guidelines *per se* are regarded as inappropriate and, if so, on what grounds. It may also be that individuals will seek to have levels of pollutants in their homes monitored and, if guidelines are exceeded, will press landlords to take action to reduce levels. The guidelines if used as suggested above are in so sense mandatory or in any sense enforceable; they are simply guides to planning. However, pressure on landlords to reduce levels of pollutants that significantly exceed the guidelines should not be regarded as unwelcome by the Department of Health.

(ix) What other processes, policies or operations would need to be put in place if such guidelines were to be set?

If the guidelines are used as suggested above no further policies etc, would be needed.

Conclusions

16. Work on the effects of indoor exposure to air pollutants has lagged significantly behind work on the effects of outdoor exposures. This is in part due to the different methods that are available for addressing these problems. Building planners, however, need guidance on acceptable levels of indoor air pollutants and for this purpose alone (at this stage) a series of indoor air quality guidelines are proposed.

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ANNEX A

INSTITUTE FOR ENVIRONMENT AND HEALTH

INDOOR AIR QUALITY - A NEW START

Discussion paper on setting guideline values for indoor air pollutants in the home environment

OCTOBER 1999

The Institute for Environment and Health was established by the Medical Research Council at the University of Leicester in 1993. The Institute is partly funded by the Department of the Environment, Transport and the Regions, the Department of Health and other Government Departments and Agencies by way of specific research and consultancy contracts.

This discussion paper has been produced by Institute staff to inform delegates at the workshop "Indoor Air Quality - A New Start" of the feasibility of, and need for, national guideline values for indoor air pollutants in the domestic environment.

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SETTING GUIDELINE VALUES FOR INDOOR AIR POLLUTANTS IN THE HOME ENVIRONMENT: A DISCUSSION PAPER

Introduction

This discussion paper addresses the feasibility of, and need for, national "guideline values" for indoor air pollutants in the domestic environment. It outlines the purpose and practicalities of setting such guidelines for the UK and the consequences of doing so.

This paper covers the following issues:

* Rational for setting guidelines
* Purpose and application of guidelines
* Selection of priority pollutants
* Establishment of guideline levels
* Measurement protocols
* Consequences of establishing indoor air quality guidelines

Workshop delegates are invited to consider and discuss the ideas presented in this paper and to provide comments and advice on setting indoor air guidelines for homes in the UK.

Rationale

Good indoor air quality is important as people spend up to 80-90% of their time indoors, approximately 75% of which is at home. The requirement for indoor air guidelines was recognised by the Commons Environment Select Committee which, in its 1991 report on indoor pollution[1], recommended that "the Government develop guidelines and codes of practice for indoor air quality in buildings, which specifically identify exposure limits for an extended list of pollutants…" In 1994, the British Government declared an intention to set and publish guidelines for indoor air quality[2].

The primary objective of setting guidelines is to identify levels of indoor pollutants below which there is likely to be no significant effect on the health and well-being of the population.

Purpose and application of the guidelines

It is suggested that guidelines should be advisory, not prescriptive. In essence, a guideline value would represent a concentration level which, when exceeded, might invoke actions to reduce levels in the room or building concerned. It would be considered a reasonable target figure enabling in most circumstances and for most individuals, the avoidance of detrimental effects on health. Importantly, the

[1] *Indoor Pollution: sixth* report of the House of Commons Environment Committee HMOS, 1991
[2] *This Common Inheritance* - 3rd year report, HMSO, 1994

guidelines would underpin the development of packages of information and advice for householders on how to manage their homes to achieve good air quality. (Separate consideration would need to be given to the application of the guidelines in other locations and situations - for example in schools, hospitals and other "public places".)

The existence of an indoor air guideline level for a particular substance would provide the basis for a householder, for example, to gauge whether he/she should take action to reduce exposure to that pollutant, and also would be a guide for regulatory bodies on the development of further control policies and other activities.

Establishment of guideline levels should facilitate, through the use of modelling techniques, the setting of appliance and/or product emission standards to help control pollution at source. This would have important applications for consumer protection and possibly also building regulations and housing fitness standards.

It would appear appropriate to contemplate setting guideline values only where control and reduction strategies and routine measurement methodologies are available. The basis and criteria for setting guideline levels would of course need to be made explicit at the outset.

Selection of priority pollutants

It is presumed that guidelines would be set, in due course, for all common components of indoor air that pose a threat to the health and well being of the occupants. In the first instance, priority pollutants would need to be identified that are a particular demonstrable hazard to people in their homes, based on health and toxicological data. The World Health Organisation (and in the UK, EPAQS) has set a number of health-based air quality guideline values that could be used as a starting point, and some countries have already specifically considered indoor air standards (see below).

Delegates are invited to consider which pollutants might be included in such a list of priority pollutants and whether these should be restricted to chemical substances or should include biological contaminants such as moulds, pet allergens and house dust mites. In principle, guidelines could also be set for physical parameters such as temperature, humidity and dampness. A table of possible priority pollutants is given in Annex 1. [N.B. Radon is already subject to important Government control activity and a recommended "action level" has been set. Although an important indoor air pollutant, radon is therefore outside the scope of this discussion. Further it is suggested that it would be inappropriate to set guideline levels for asbestos, man-made mineral fibres or environmental tobacco smoke.]

Establishment of guideline levels

As already indicated, guideline levels should be health based with appropriate consideration of particularly vulnerable or sensitive members of the population, and taking due regard of any data on the concentrations commonly found in homes. It is important that the guidelines should be credible, and appropriate use should therefore be made of guideline values or standards for indoor or outdoor air already set or proposed by other countries or by recognised international bodies. The World Health Organisation's "Air Quality Guidelines for Europe" (see Annex 1) and the residential indoor air quality guidelines formulated by Canada, Denmark, Germany and Norway, for example, would be of special relevance (Annex 2). Particular attention should also be paid to recommendations made by DETR's Expert Panel on Air Quality Standards (EPAQS) and the Department of Health's Committee on the Medical Effects of Air Pollutants (COMEAP).

In some cases, setting a guideline value may include pragmatic consideration of the potential for achievement (the "as low as reasonably practical" principle). Also it may sometimes be necessary to have more than one value, i.e. a peak concentration guideline and a longer term mean concentration value. The issue of *concentration* versus *exposure* would need to be explicitly addressed.

Finally, it would seem rational to consider guideline levels only if the pollutant can be both monitored and controlled.

Measurement protocols

The concentration of a particular pollutant in a building or in a room is not constant. As well as varying according to source strength and emission rate, it changes with location and time. The detected level is usually dependent upon distance from source, distance from walls, furniture and fittings (due to absorbence/re-emission) and vertical height (due to buoyancy/stratification). It is also affected by air currents (due to convection and/or ventilation) and is to some degree dependent upon measurement technique and/or equipment. In addition, prevailing temperature and humidity conditions can affect both chemical emission rates and chemical speciation, and local human activity can have a marked effect on measured concentrations.

For these reasons, it is considered important that if a guideline level is set for a particular substance, advice should be given on how that substance is to be sampled and analysed. A standard methodology is required which provides a concentration figure relevant to personal exposure to the particular pollutant in that environment. In the case of pollutant emission from a point source within a room (e.g. CO or NO_x release from a gas burning appliance), it is clear that the measured concentration would usually be much greater close to the appliance than at some distance away; it would also be influenced by how the appliance was being used and the ventilation conditions in the room. Whether to measure "peak" or average concentrations would depend upon the clinical effects of the pollutant in question, and would need to be specified in the guideline.

To avoid inconsistent results during monitoring and to provide a measurement which is relevant to human exposure, it is probably essential for any guideline values to be accompanied by recommended sampling and measurement protocols.

Consequences of establishing indoor air quality guidelines

There are a number of likely and potential consequences of setting indoor air guidelines that merit discussion. For example, consideration would need to be given to the possible requirement for national co-ordinating and/or quality assurance programmes for contractors performing measurements. Would the Government also be obliged to establish a monitoring system to sample a representative number of homes over time to check "compliance"? These considerations have financial and resource implications. Also legal considerations could be important, for instance in the case of householder *versus* landlord responsibilities when guideline levels are breached. More generally, there is a possibility that, if not introduced with sufficient care, guideline values could accelerate the already existing trend to solve problems by litigation.

It is envisaged that the guideline levels would be used in the development of both control actions, and advice for householders, with the exception that, if the advice was followed, guideline levels would not be exceeded and individual measurement of pollutant levels would generally not be necessary. It would however be essential to address the usefulness and practicality of such advice. If the establishment of guideline levels led to the setting or recommendation of product emission standards, consideration would have to be given to the methods by which these standards would be applied, i.e. through legislation or voluntary labelling.

Improvement of indoor air quality through providing consumer choice and advising consumers on the proper use of products is important, whether or not this advice is driven by the pursuit of specific air quality guidelines. Similarly the encouragement of improved technologies in product and appliance manufacture to reduce emissions is important in its own right.

One possible consequence of having IAQ guidelines is increased use of mechanical air cleaning devices. This could be an unwelcome move for a number of reasons. Although some devices are reasonably effective at removing suspended particulate matter and some gaseous substances, no cleaner is able to totally eliminate all hazardous airborne substances, and such systems have a finite lifespan before replacement sorbents or filters are required. They may cease to function effectively and even re-emit gases if not properly serviced or maintained. Ion generators may create rather than solve indoor air quality problems because they produce ozone. The provision of guidance on the use and effectiveness on air cleaning devices would therefore need to be considered.

Summary

Indoor air quality guidelines would be expected to assist individuals and public agencies in making consistent judgements about the need for remedial measures (or other courses of action) to improve air quality in the home. In the longer term it is envisaged that the guidelines could be used as a basis for developing or modifying building codes, ventilation requirements, and product standards for construction and household products, household appliances, furniture and furnishings. But there are some important - possibly negative - consequences of setting guidelines.

Delegates are invited to consider the issues presented in this paper and to provide opinion and advice on the formulation of indoor air guidelines. A number of specific questions should be addressed, including:

- What form should the guidelines take and where should they apply?

- What are the "priority" pollutants for guideline setting?
- Could or should existing guideline levels (e.g. WHO, EPAQS) be used "off the shelf"?
- What can be learned from similar initiatives elsewhere?
- How should sensitive or "at risk" groups be addressed?
- What is the best approach to ensure appropriate and accurate measurements?
- What more (if anything) needs to be known before guidelines can be set?
- What problems might result from setting IAQ guidelines?
- What other processes, policies or operations would need to be put in place if such guidelines were to be set?

ANNEX 1

Possible priorities for Indoor Air Quality guidelines

Pollutant	**UK Monitoring Information**	**Measurement Methodology**	**Existing WHO Air Quality Guideline**	**Key Health Impact(s)**	**Potential Cause for Health Concern**	**Potential for Sourc Control**
Nitrogen dioxide	1†*	1C	200 µg/m^3 (1 hr) 40 µg/m^3 (1 yr)	Respiratory	M	H
Formaldehyde	1†*	1P	100 µg/m^3 (30 mins)	Respiratory	M	M
VOCs (Total)	1†*	1P	None	Respiratory, CNS	L	M
Benzene	2†*	2P	[Unit Risk]	Cancer	M	M
Carbon monoxide	2*	1C	100 µg/m^3 (15 mins) 60 µg/m^3 (30 mins) 30 µg/m^3 (1 hr) 10 µg/m^3 (8 hrs)	Death, CNS	H	H
ETS	2(*)	2P	None	Respiratory, Middle Ear Disease, SIDS, Cancer	H	H
Particles# (PM_{10})	3(*)	2C	[Unit Risk]	Respiratory, CVD	M	M
Pesticides	4(*)	3P	None	Various	(M)	M
PAHs (BaP)	4(*)	3P	[Unit Risk]	Cancer	M	L
House Dust mites	1*	2P	None	Asthma/ allergy	H	M
Pet allergens	2(*)	2P	None	Asthma/ allergy	H	M

Pollutant	UK Monitoring Information	Measurement Methodology	Existing WHO Air Quality Guideline	Key Health Impact(s)	Potential Cause for Health Concern	Potential for Sourc Control
Moulds	2†*	2P	None	Asthma/ Allergy	M	M
Bacteria	4*	3P	None	Asthma/ Allergy, Infectious Disease	(L)	(M)

Table of symbols

*	IEH Assessment published
( )	In preparation
†	BRE ALSPAC Study

1	Good
2	Fair
3	Poor

P	"Passive" only
C	Continuous/Real-time

H	High
M	Moderate
L	Low
( )	Uncertain

#: Commonly taken to be PM_{10} or $PM_{2.5}$, or sometimes Total Respirable Particles or Total Suspended Particulates

ANNEX 2

<u>Quantitative guideline values for indoor air pollutants identified by various national government bodies/committees</u>

A number of countries have, either in the past or more recently, considered quantitative guidelines for residential air quality. Some administrations have published guideline values for one or more pollutants.

The first such "standard" appears to be the German guideline on formaldehyde. In 1977 the German Federal Health Office recommended a figure of 0.1 ppm for formaldehyde in indoor air, and many other countries followed suit.

An extensive national list of proposed indoor air guideline values was produced in 1987 (revised in 1989) by the Federal-Provincial Advisory Committee on Environmental and Occupational Health of the Canadian Department of Health and Welfare (detailed in the attached table). Similar proposals have come from Germany and Norway (see table) and the Nordic Committees on Building Regulations and Indoor Climate, which proposed guidelines for 20 chemicals (carbolic acids, phenols, glycol ethers, aldehydes, terpenes and alcohols). In Poland the Minister of Health and Social Welfare has issued a decree determining the maximum allowed concentrations of 35 harmful substances in indoor air. Many of these are organohalides and other hydrocarbons. A sample of those guideline values considered to be most relevant is also shown in the table.

In the USA there is no uniform approach to indoor air guidelines, and some states (e.g.California) have been more proactive than others. Nevertheless, the retulations or guidelines promulgated by the states are for the most part limited in scope and target specific issues such as smoking or mechanical ventilation codes. Similarly in Australia the use of "indicators" of good indoor air quality are used rather than quantitative guidelines.

SOME PUBLISHED QUANTATIVE INDOOR AIR GUIDELINE VALUES

Canada 1987

Substance	Guideline concentration	Averaging period
Carbon dioxide	6,300 mg/m^3	[Not stated]
Carbon monoxide	11 ppm (13 mg/m^3) 25 ppm (28 mg/m^3)	8 hr 1 hr
Nitrogen dioxide	100 µg/m^3 480 µg/m^3	"Long-term" 1 hr
Ozone	240 µg/m^3	1 hr
Particulate matter ($PM_{2.5}$)	40 µg/m^3 100 µg/m^3	"Long-term" 1 hr
Sulphur dioxide	50 µg/m^3 1000 µg/m^3	"Long-term" 5 mins
Water vapour	30-80% RH (summer) 30-55% RH (winter)	[Not stated] [Not stated]
Formaldehyde	120 µg/m^3	5 mins
Formaldehyde (carcinogen)	120 µg/m^3 ("Action level) 60 µg/m^3 ("Target level)	[Not stated] [Not stated]

Note: In addition, "substances with recommendations for controlling exposure" were listed including biological agents, ETS and PAHS.

Germany 1999

Substance	GVII*	GVI**	Averaging period
Toluene	3 mg/m^3	0.3 mg/m^3	1-2 weeks
Styrene	0.3 mg/m^3	0.03 mg/m^3	30 mins
Dichloromethane	2 mg/m^3	0.2 mg/m^3	24 hrs
Carbon monoxide	15 mg/m^3 60 mg/m^3	1.5 mg/m^3 6 mg/m^3	8 hrs 30 mins
Nitrogen dioxide	60 $\mu g/m^3$ 350 $\mu g/m^3$	6 $\mu g/m^3$ 36 $\mu g/m^3$	1 week 30 mins

In addition a guideline value for TVOC (as an indicator) of 1-m mg/m^3 was proposed as a level that should not be exceeded in a room with permanent occupancy. Guidelines for pentachlorophenol were given in terms of human biomonitoring.

*GVII = Guideline value II; a health related value based on current toxicological and epidemiological knowledge.

**GVI = Guidelinve value I; the concentration at which a substance (individually) does not give rise to adverse health effects even at life-long exposure.

Norway

Substance	**Guideline concentration**	**Averaging period**
ETS	1 µg/m^3 (smoke-free areas) 10 µg/m^3 (no-smoking areas in restaurants)	[Not stated]
House dust mites	1 µg Der pI allergen/gram dust or 50 mites/gram dust	[Not stated]
Formaldehyde	100 µg/m^3	30 mins
Suspended particles ($PM_{2.5}$)	20 µg/m^3	24 hrs
Carbon dioxide	1800 µg/m^3	[Not stated]
Carbon monoxide	10 mg/m^3 25 mg/m^3	8 hrs 1 hr
Nitrogen dioxide	100 µg/m^3	1 hr

Poland (1996) [Selected pollutants]

Substance	Maximum allowable concentration	Averaging period
Ammonia	300 µg/m^3 300 µg/m^3	24 hrs 8-10 hrs
Benzene	10 µg/m^3 20 µg/m^3	24 hrs 8-10 hrs
Formaldehyde	50 µg/m^3 100 µg/m^3	24 hrs 8-10 hrs
Xylene	100 µg/m^3 150 µg/m^3	24 hrs 8-10 hrs
Ozone	100 µg/m^3 150 µg/m^3	24 hrs 8-10 hrs
Pentachlorophenol	5 µg/m^3 10 µg/m^3	24 hrs 8-10 hrs
Styrene	20 µg/m^3 30 µg/m^3	24 hrs 8-10 hrs
Carbon monoxide	3000 µg/m^3 6000 µg/m^3	24 hrs 8-10 hrs
Toluene	200 µg/m^3 250 µg/m^3	24 hrs 8-10 hrs

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