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1987 WORKSHOP PROCEEDINGS

INDOOR AIR QUALITY

Acceptable Standards and Building Design

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NSCA WORKSHOP 1987 - "INDOOR AIR QUALITY - ACCEPTABLE STANDARDS AND BUILDING DESIGN"

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tor: Jane Dunmore

EDITOR'S NOTE

This volume of the Proceedings of the 1987 NSCA Workshop contains all but one of the papers presented, and the report of discussions on those papers. One speaker at the Workshop not represented in these proceedings is Dr. C.A.C. Pickering. Unfortunately, owing to pressure of work, Dr. Pickering was unable to find the time to rewrite his speech so that it would make a paper suitable for publication. Accordingly, we apologise for the non-inclusion of this paper and the record of the discussion upon it.

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1987 WORKSHOP
25–26 MARCH
MANCHESTER

INDOOR AIR QUALITY
ACCEPTABLE STANDARDS AND BUILDING DESIGN

CHANGES IN BUILDING DESIGN,
USE AND VENTILATION
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INTRODUCTION

This paper is intended to set the stage for the Workshop by describing recent trends in the design, use and operation of buildings that may affect the indoor air quality. There have been many minor changes due to energy considerations, the use of modern materials and a better awareness of the need to improve occupant comfort. In this brief review of some of these, no attempt is made to go into great detail, because the speakers which follow will address each sector separately.

INDOOR AIR QUALITY

We should commence by defining what factors are generally accepted to embrace "air quality" in the indoor environment. "Indoor air quality" is not easy to define. In addition to the need to control physical or biological pollutants, even water vapour (or the lack of it) which ought to be benign, can produce discomfort and must be controlled. And is air temperature itself a parameter of air quality? For it is the very business of ensuring acceptable indoor temperatures with a minimum use of energy that creates the dilemma of balancing acceptable conservation measures with acceptable "air quality". And what kind of "quality" would describe a perfectly clean, humidity-controlled and correct-temperature room if there was a 70 mph gale blowing through it? Even air velocity, then, must be considered in the balancing act.

The common definition of indoor air quality is, "The quality of air that affects one's health and wellbeing". We believe that health and wellbeing can be affected by at least the following:

1. <u>Chemical Pollutants</u>

   e.g. NO_x Radon
   CO Organic vapours

2. <u>Physical Pollutants</u>

   e.g. Dust Tobacco smoke
   Pollen Positive ions
   Asbestos

3. Biological Pollutants
   e.g. Sick Building Syndrome Humidifier Fever

4. Water Vapour
   (Too much, or too little)

5. Air Temperature
   (Too hot or too cold)

6. Air Velocity

Conventional consideration of "air quality" does not normally include moisture, temperature and velocity, but we believe that all six categories above must be considered together, especially in the context of energy use.

Are there acceptable and recognised standards for the maximum (or minimum) levels of these factors? In general the answer is a surpising "no"; only the guidelines shown in Table 1 are available:

CHANGES IN CONSTRUCTION TECHNIQUES

For a variety of reasons, and primarily as an energy conservation measure, today's buildings are being made more airtight than in the past(4). Tightening up of the leakiness of building structures is being carried out both at the design stage and by retrofit of various measures to older properties, and this trend applies to dwellings, offices, commercial and institutional buildings and manufacturing premises. The very reason for this trend, aimed at reducing the natural ventilation rate, has an immediate effect on the rate of build-up of indoor pollutants and thus lowers indoor air quality.

Of all the relevant Acts of Parliament and Building Regulations affecting ventilation requirements for UK buildings(5), there are no overall regulations governing building airtightness, although they do apply to leakiness of such components as weather stripping, window systems and building joints. Thus the actual trend towards increasing airtightness is a voluntary thing, recognising this to be a common-sense approach. The increasing use of plastic foam

insulation blocks in cavity brickwork, and the increasing trend towards timber frame buildings which are far easier than masonry buildings to "wrap up" in plastic sheeting during construction, has certainly assisted this trend.

It is most important to realise that one can quite easily go too far in airtightness, and if one "imports", for example, Scandinavian airtightness standards and construction techniques, one must simultaneously "import" controlled ventilation measures in the same building.

Information on recommended ventilation rates and approaches to ventilation are given in Part B of the CIBSE Guide(6). In Sweden and Norway legislation has been introduced concerning the overall airtightness of dwellings - standards which also require the provision of positive ventilation means. The only other country in which whole building airtightness standards are currently being considered is the United States.

In this country it is generally recognised that an air change rate of between 0.7 and 1.0 air changes per hour is ideal. This level is set primarily to maintain acceptable humidity levels. It is remarkably difficult to find published data on how the natural ventilation rate of "typical" buildings has dropped in the last 15-20 years. Indeed the extensive literature database of the Air Infiltration and Ventilation Centre at Bracknell contains no information on this. If leakiness of buildings has in fact dropped only by a matter of 2 or 3 fold, as seems probable, the contribution of this factor alone to increased indoor pollution is not great. However, as will be discussed later, it is likely that there are many "non-typical" buildings in which occupiers have overdone the sealing-up process.

Another trend in construction techniques which is of concern is the increasing use of resins, solvents, adhesives, etc in construction, which can and do emit organic vapours especially during the first few months of occupancy. This, coupled with lower ventilation rates, does give cause for concern. The materials and sources of concern include formaldehyde from resin-bonded wood products, adhesives and wall insulation, and solvents such as toluol and butyl acetate from glues, cements, foams, paints and floor titles. On the positive side, asbestos, formerly used widely as a thermal and sound insulation material, has been eliminated from new construction since its hazards were recognised.

Over the past 15 years or so there has been a major increase in the number of large commercial buildings employing air-conditioning, especially in the London area. Both new construction and refurbishment of older buildings more often than not includes a full air conditioning system. While part of the need for this is due to increased heat release within buildings by, for example, computers, the major reason is simply that commercial buildings can command a higher rental if they are air conditioned, whether it is needed or not. Once occupants have become used to working in an air conditioned environment they appreciate the benefits of working on warm days with closed windows, leaving traffic noise and city air pollution outside, and this satisfaction then spreads to justify the need for even more air conditioned buildings by others. Air conditioned buildings cost more to run, and there are therefore great incentives to reduce this cost by such measures as reducing the fresh air make-up. So this commercial trend towards driving up rental income can, and sometimes does, have a potentially deleterious effect upon indoor air quality.

CHANGES IN BUILDING USE

It has been said many times that the worst source of indoor air pollution is "people". Not only pollutants emitted by people themselves, but by their activities indoors. In commercial and institutional buildings the proliferation of computers and electrical and electronic gadgetry of various types has had a remarkable effect on the local generation of heat. While this is not a major problem in small or narrow-plan buildings in winter, it creates a vastly increased need for air conditioning - even throughout the year in deep plan buildings. Then, coupled with the wish of the system designer and operator to conserve energy, fresh air make-up levels are lowered and indoor pollution rises.

Computers and word processors incorporating VDUs generate a surplus of positive ions in the air, believed by many to be a pollution problem. The decay rate of these ions is reduced in low humidity levels - while the control of humidity has

more recently been exercised by the air conditioning engineer, so these things are intricately bound together.

However, occupiers of buildings are encouraged to introduce energy saving measures themselves, and some of the measures they take can 'overdo' the tightness of a building and lead to indoor pollution. Simple measures such as draught stripping and fitting double glazing can lead to excessively sealed houses, and the age-old method of control - "seal up the windows until the chimney starts smoking" - is no longer appropriate to houses without open fires.

Perhaps the demise of the open fireplace was not such a good thing after all. Many new central heating boilers are fitted with balanced flues in which the combustion space is completely sealed from the indoor environment. Fireplaces have been totally blocked or throttled down to take gas fires or closed combustion stoves. While these things definitely save energy, they allow pollutants from other sources within the building to build up more rapidly in an uncontrolled and undetectable way.

There is no simple way by which the householder or office manager can measure air-change rates himself - it has to be done by an outside expert by measuring the decay rate of a specially introduced tracer gas or by pressurising the entire building with a large fan temporarily mounted in a door or window.

Water vapour is not normally considered as a pollutant, but it certainly has an adverse effect on indoor air quality. High humidity encourages the growth of moulds, whose spores are definitely harmful to many people. Condensation on windows and in roof space can cause rapid deterioration of the building fabric. High humidity levels are encouraged by tightening buildings, but are also created by some modern living trends. The bathroom shower has made a dramatic appearance into British homes and is a major source of water vapour. The electric tumble-drier is another recent growth item, and the difficulty of venting these through an 11" brick wall leads to indoor humidity levels rising. The tendency of people to replace or augment their traditional heating with unvented portable cylinder-gas heaters is another major source of water vapour troubles.

There has been a steady trend for the public to make more use of their leisure time in buildings designed and operated just for this purpose. For example, two decades ago the control of indoor environments in indoor swimming pool halls was not a major issue, while nowadays it is a major subject for discussion at Building Services conferences. Concern is expressed about humidity levels, chlorine or ozone contents, as well as temperature and air velocity profiles.

ATTITUDES TOWARDS SMOKING

There has been a steady and growing realisation that "second hand" tobacco smoke, or passive smoking, is an unpleasant, irritating and even hazardous pollutant, and a number of steps have been emerging to combat this problem. Ventilation strategies have been changed, or designed specially to cope with the problem; no-smoking zones have been set up in many public buildings, just as they have existed in public transportation for years, and now whole buildings or large parts of buildings are being designated as no-smoking areas. The situation is changing quite rapidly as the smoking members of the community are either forced to or agree to accept a measure of control. An interesting example of this dynamic and changing situation is apparent in the new conference centre of the Chartered Institute of Building Services Engineers (CIBSE). The architect's brief was to produce a main conference room with full air-conditioning to cope with smokers present, but not to air condition the remainder of the building, and it was built this way. However in these changing times the first action of the CIBSE Council when meeting in the new centre was to designate the main conference room a no-smoking zone, so that visitors to the building now have to produce their pollution in the remainder of the building, which was not designed to cope with it! This may not be an isolated example of how rapidly changing attitudes towards smoking are moving faster than engineering can cope.

Dealing with tobacco smoke pollution creates a classic dilemma of priorities - which is more important, health or comfort?

Uncomfortable conditions are soon recognised by the building

occupants, but unhealthy conditions are not.

The technical literature contains various recommendations on the acceptable concentration levels of the most critical constituents of tobacco smoke and differing information on the rate of release of these constituents during smoking. Taking a consensus of the available data, the following range of ventilation rates may be derived.

Criterion	Fresh air requirement m^3 per cigarette
Respirable particles (health)	86 to 280
Acceptability of odour to 80% of visitors (comfort)	120
Odour retention in fabrics (comfort)	60 to 80
Eye irritation (comfort)	50
CO concentration (health)	3.6 to 8.3
Acrolein concentration (health)	1.0 to 7.0

In this case, the health effects arising from respirable particles is the most critical but if some form of suitable filtration is used to reduce particle concentrations, then the minimum ventilation rate will be governed by a comfort criterion, the provision of odour acceptability. In the absence of smoking, it is the comfort criterion of the body odour acceptability that usually dictates the ventilation requirement (7 to 8 l/s per person) for human occupancy. In the 1981 issue of ASHRAE Standard 62 (3), the minimum ventilation requirement (2.5 l/s per person) is based on a health criterion, limiting CO_2 concentration to 4500 $mg/^3$, although it is understood that the revised version due in 1986 may revert to an odour-based comfort criterion.

CHANGES IN VENTILATION METHOD

There is a wide variety of techniques which have been adopted in the past fifteen to twenty years which generally fall into the category of "ventilation" which have effects on air quality. The majority of these changes have been introduced as energy-saving measures. In general the trend is to introduce less fresh air make-up by increasing the recirculation ratio, especially in air conditioned buildings.

Controlled ventilation seems to be the single most useful method of striking the balance between air quality and energy use. In order to control the ventilation of a building, not only must some modulated ventilation system be provided, but the extraneous air leakage into the building must be at or below the lowest fresh air requirement.

The addition of heat exchange systems to recover heat from the warm air exhausted from buildings can also reduce the energy implications of providing adequate ventilation but, again, such systems are effective only if the natural air infiltration is minimised.

We now see an increasing use of heat recovery systems used to exchange heat between outgoing air and fresh air make up. Devices include run around coils, plate heat exchangers, heat pumps and heat pipes. The introduction of these makes it possible once again to increase fresh air make-up rates and therefore improve indoor air quality.

Understandably, the greatest efforts in reducing the uncontrolled air infiltration into buildings and providing controlled ventilation have been in those countries with severe climates, notably Scandinavia and Canada, motivated by comfort considerations as well as energy saving. In temperate climates, the case for tightly sealing buildings and changing from natural to mechanical ventilation, even with heat recovery, is much less clear. Hence the continued use of natural ventilation and the demanding requirement to predict the rates of air flow that are subject to the vagaries of the ever-changing climate. The impact of occupant behaviour on ventilation is also significant and is the subject of continuing study.

In the ideal situation, the amount of fresh air make-up can be controlled by a sensor responding to indoor air quality. In this way the introduction of fresh air, and its corresponding energy requirement is maintained at a minimum commensurate with maintaining an acceptable standard of indoor quality.

One of the problems in the selection of a measurable control parameter that suitably represents the air quality. Whereas

CO_2 has been shown to be a reliable marker for body odour it is not necessarily indicative of other airborne constituents. For example, cigarette smoking affects CO concentration much more than CO_2 and it has been suggested that the use of a CO sensor could provide an override to CO_2 control in spaces where smokers are present. Feasibility studies are underway in the USA on a detector for particulate concentration control and in Holland on a multiple gas sensing system based on electrical conductivity changes. CO_2 controlled demand-ventilation systems are already in use, but due to their high cost they have been restricted to high-occupancy buildings at present.

The savings in energy resulting from the use of CO_2 controlled ventilation in buildings with varying occupancy levels, such as schools, department stores and offices, range from 10 to 40%.

A new ventilation technique that is being introduced in some specialised commercial buildings is to introduce fresh air at floor level or even through the furniture and fixtures, and remove stale air at ceiling level. In this way the occupants' working zone is fed with the cleaned, purest air, and bulk pollution of the entire building is without effect. Also in this way, lower volumes of air have to be conditioned and heated, and the occupant finds himself in a "microclimate" of clean air.

SUMMARY

In the 1960s and before, the principal aim of the heating and ventilating engineer was to provide indoor comfort, which included the removal or elimination of noxious or easily detectable impurities and to maintain adequate temperature levels. In the 1970s the rapidly increasing price of fuel led designers to concentrate mainly on the saving of energy, sacrificing some air quality factors and giving priority to temperature alone. The principal techniques were the reduction of fresh air ingress by making buildings more airtight and/or by reducing fresh air make-up levels in mechanical ventilation systems. Coincident with this activity, new organic materials were being introduced into building construction as adhesives, insulants and timber-bonding materials, and into the furniture and fittings

used indoors. The onset of chemical pollution as a health hazard, rather than a discomfort hazard, became of major concern.

In the 1980s more emphasis is being applied once again to indoor air quality. Standards and recommendations are being considered to ensure that minimum fresh air levels are maintained; some of the hazardous sources of indoor pollution are being removed or suppressed; new ventilation techniques which monitor some indication of pollution such as CO_2 or CO, and couple this signal to the fresh air make-up, are being introduced. Completely new ventilation strategies are being developed by which quite small quantities of really clean air, introduced in critical areas of the building, can save on overall building operating costs while maintaining clean local conditions.

We can look forward in the future to a more careful consideration of the balance between energy use and indoor air quality. The building designers and the heating and ventilating system suppliers now know far more about optimising this balance than they did 20 years ago. Much, however, will be left in the hands of the building occupant, who can undo much of the technology designed into the building by behaving irresponsibly in interfering with controls, ignoring smoking regulations, or even opening windows on inappropriate occasions.

In conclusion, we should remember that once an indoor air quality problem has been identified and a required standard has been set, the HVAC engineer can provide the means to achieve acceptable indoor conditions. But he cannot aim at a "moving target" in a cost-effective way. And he can do little to preserve the indoor environment if the outdoor air is already heavily polluted.

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INDOOR AIR QUALITY
ACCEPTABLE STANDARDS AND BUILDING DESIGN

THE INFLUENCE OF ENERGY CONSERVATION MEASURES

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THE INFLUENCE OF ENERGY CONSERVATION MEASURES

by
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When I looked through the programme for this event, I realised that I would be a Daniel in the lion's den, preaching to those who might not wish to hear the message about energy conservation. However, having listened to Derek Gregory and having had the opportunity to read the preprinted papers, notably that by Chris March, I realise that I do not have to warn you in "babies and bathwater" terms about energy conservation, which is the metaphor that originally sprang to mind. My message really is that a balance needs to be sought between sensible regard for indoor air quality and measures directed towards energy conservation. Having said that, I believe it is absolutely critical for us all to appreciate just how many benefits can accrue from a sensible investment programme in energy saving and how many benefits will be foregone, by the nation as a whole, if we alter that balance too much.

I should like to begin by explaining what the Association for the Conservation of Energy is. We were formed by a number of major companies active within the energy conservation industry, to carry out three roles: to encourage a positive national awareness of the benefits of and the need for energy conservation; to try to help establish a sensible and consistent national policy and programme; and to increase investment in all appropriate energy saving measures.

In order to put this into context, I should give some indication of Britain's position on the whole energy saving front. As many of you will be aware, last year was Energy Efficiency year. Such a year was called into being because when the present Secretary of State for Energy took office in 1983, he had a look at some of the international comparison figures and those showed that as a nation we wasted energy almost more than any other major Western European power. The wastage entailed all sorts of detrimental financial aspects, as well as many detrimental social aspects.

The Secretary of State declared that of the £35 billion per year or so that the nation spent on energy, at least 20% could be saved via thoroughly cost effective, tried and tested energy saving measures. In fact, that savings figure is probably a very modest one. I remember that when the head of Energy Technology Research Unit in Harwell gave evidence to the House of Commons Energy Committee (great supporters of the whole drive towards greater energy saving) he constructed a case whereby 40% of current energy expenditure could easily be saved without getting involved in all sorts of strange and untried measures. Even assuming the 20% figure, this would mean knocking some £7 billion off our nation's fuel bill, thus providing £7 billion which the nation could better use than squander.

I should like to explain why energy conservation is so important, and outline what can be achieved in this area. A number of factors can assist with improved energy efficiency in the home. The first is not so much a financial one, but rather to do with attaining greater comfort and improved health as well.

Many of you will be aware that there are great numbers of people living in this country, even now in the late 1980s, in cold, damp, miserable homes. There are at least two and a quarter million households in receipt of fuel allowances, which is a very basic minimum subsistence level - this is a Government response to people who cannot afford to heat their homes satisfactorily. The amount of money allocated to fuel allowances has quadrupled while this Government has been in office and it now costs the taxpayers some £400 million to provide minimum heat for these two and a quarter million households. But that said, there is at the moment no attempt made to ensure that the families in receipt of fuel allowances actually live in reasonably comfortable homes without howling draughts coming through their living rooms. To my mind it is absolutely daft that we cannot have a

tie-up between the home insulation programme and the provision of fuel allowances to low income families. It is rather like trying to fill a bath without putting a plug in.

I noted that Derek Gregory very rightly made the point that, even in the last twenty years, during which period we have started to talk energy conservation to an extent which was totally unheard of in the 1960s, there has only been a two or threefold improvement in the way in which we have approached the job. If we can try to reduce the fuel bills for those in low income households, who have great difficulty in actually paying for their fuel (and you will know the problems of both the Gas and Electricity Boards with what they would term "bad debtors") we shall actually free resources which can be spent on rather more sensible measures than ploughing money back to British Gas or the electricity industry. There is a great deal to be said for retaining that money in people's pockets to be spent in their own locality, thereby actually improving the local economy, rather than sending it to centralised organisations such as the electricity and gas industries.

I believe, too, that we are talking about a reduction in worry for people. There is a continuing problem, particularly for those who have either elderly relatives or small children livin with them, the "at risk" section of the community, about how to keep homes sufficiently warm. There is a great variety in the proportion of disposable income that people spend on heating and it is true to say that those who have small children or dependant relatives, or who are elderly people living by themselves, spend a far higher proportion of their disposable income on trying to keep warm: 25%-30% in many cases. That is a social problem that we can try to address by reducing fuel bills.

I also want to touch on the question of actually improving the value of property. There is no doubt that a home which is cheaper or more efficient to run and which is more comfortable to live in, actually increases in value. (I am not talking just about the capacity for people to spend money on double glazing; it never ceases to amaze me how much perceived added value is attached to something like double glazing, which in terms of energy pay-back is not as good as simple measures such as draught stripping. I think it is due in large part to perceived values quite apart from the purely energy side, such as security and improvement in the look of the property) Fundamentally, however, within individual households it is a matter of trying to reduce waste, and that applies to the individual company too.

So far as the company is concerned, whether in an office or factory building, the most tangible benefits are improvements in competitiveness and profits. That is one of the principal reasons why the Government has become involved in the whole energy efficiency campaign; overheads in industry have been too high and industry, commerce and indeed local authorities have to be persuaded to put money into what is fundamentally a gilt edged investment. The rates of return are likely to be way above anything that any money markets can offer: 30%-40% on conventional energy saving measures. It is very difficult indeed for industry to see other ways in which such returns can be achieved particularly since the introduction of energy saving programmes, whether in offices or factories, entails no loss of jobs. There really are very few programmes that can actually be introduced by companies, or indeed public authorities, which as a corollary to success do not involve, eventually, some shedding of jobs. I would put to this audience that energy conservation is one area where undoubtedly the same number of jobs can be retained, with far greater savings and improved competitiveness. I would also emphasise the side benefits of a more content workforce due to the fact that people will actually be working in better conditions, whereas formerly they might have been subject to appalling blasts of cold, or in some cases overheated offices or factories.

Those arguments relate to individual buildings, but I should also like to put the national case for energy conservation. If we reduce the attention that we have belatedly paid as a nation to energy conservation and energy efficiency, we will to our great detriment forego a number of national benefits.

The first of these is the fact that the more energy we save, the less we have to generate in the first place, which means that we can actually reduce the need to fund the building of new power generation sources, whether these are new power stations for electricity or,say, the project in Morecambe Bay for gas. Indeed, we will cut our requirement for importing

new power sources, eg gas from Norway or even from the USSR. Avoiding the need for such imports would bring about a direct improvement in the balance of payments and internal investment would also benefit. Investment in energy saving projects shows a far better rate of return than do new power stations. In the United States, where most of the power companies are privately owned, the sums have to be done in order to satisfy the stockholders; the hard realities of the marketplace determine whether or not a new nuclear power station is a better investment than helping people to insulate their homes or their factories, or to improve the refrigerating processes or do whatever can be done to try to reduce demand. I am now convinced, both by the sums that have been offered in the US and indeed by experiments taking place in Oslo in Norway, where similar exercises are being done; and the electricity companies themselves are finding that it pays them to try to reduce demand rather than to build new power stations. That is one of the reasons why no new nuclear power station has been started in the United States for the last nine years so.

I think that a greater emphasis on energy conservation will also help to reduce the problems relating to conventional coal fired power stations. In 1986 the Society held what looked to be a very interesting conference, on acid rain pollution. This appears to be an almost insoluble problem without the expenditure of (as the electricity industry would have us believe) vast, disproportionate sums, which would force up our electricity prices to a totally uncompetitive level. I would submit that there is a very simple way of solving acid rain problems in the medium to long term, and that is to have fewer power stations. One way of ensuring fewer power stations is not to need the energy in the first place. I would also submit that another argument, on a national basis, for a greater programme of energy efficiency, is that far less land is required for energy saving than for energy generation. I was brought up in a village called Aldeburgh, which is right next to the site of the proposed new Sizewell power station. I shall not enter into the general argument about Sizewell - that would not be appropriate - but the fact remains that a considerable swathe of land will be taken up for new power generation, and the question not addressed by the Department of Energy at this stage is whether that land really needed to be taken

- is the power station really necessary?

Turning back from the energy arguments to the building stock, I believe that a concentration on energy saving will actually produce an improvement in the building stock, particularly where we retrofit areas which have become run down in our inner cities. Our Association has looked recently at the re-generation of inner city projects. We are very heavily involved in one in Sheffield at the moment, through the Neighbourhood Revitalisation Scheme, which I hope will have considerable potential for replication elsewhere. Such schemes help to generate a great number of semi-skilled and unskilled jobs. We looked at the potential for a cost-effective programme in this country for new jobs and we have identified at least 155,000 new jobs that could be generated through such a programme. At the moment we are essentially scratching the surface, but, having said that, the Local Neighbourhood Energy Action Insulation Project which helps lower income households, is now the second largest Manpower Services Commission scheme in terms of new job generation.

I am aware that for most of the rest of this Workshop, people will be looking at the problems that can accrue from over-concentration on energy saving within a building. I am the first to admit that hermetically sealing a building is ludicrous, just as ludicrous as the argument that the easiest way to save energy is to close down every factory in the country. Doubtless the Workshop will reach a common accord on the need for continuing to concentrate on appropriate air changes within the building. However, I implore you, during the discussions, to appreciate that there is a reason for wanting to save energy, not just because it is a "motherhood and apple pie" issue, but because it is of critical importance. It is critically important for social reasons, it is critically important for environmental reasons and it is also critically important for economic reasons.

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INDOOR AIR QUALITY
ACCEPTABLE STANDARDS AND BUILDING DESIGN

HAZARDOUS BUILDING MATERIALS AND THEIR PROBLEMS

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INTRODUCTION

The title of this paper is "Hazardous Building Materials & Their Problems". I will briefly explain the work we have been doing at Salford University, and the difficulties associated with identifying the extent of the problem; finally, I shall make a number of suggestions as to where we should go from now.

My colleague, Steve Curwell, and I have been engaged in an investigation into the likely risks to the health of occupants of buildings, caused by materials used in construction; not the risk to those operatives involved either in the manufacture or processing on site.

We were fortunate to be approached by Godfrey Bradman, Chairman of Rosehaugh PLC, who funded our work. I say fortunate, because it would have been extremely difficult to attract funding from the traditional routes for such a multi-disciplinary project. It also meant that we could select whomever we wanted (or should I say whom we were advised to approach) without any financial restraints.

At the outset, I must stress that neither Steve nor myself consider ourselves to be experts on matters pertaining to health, although obviously as the work has progressed our lay knowledge has improved. Indeed, we deliberately took the stance of amateurs in this area. Steve, as an architect, and myself, as a builder, are only too aware that many people think they are experts on buildings simply because they live in a house - we know this is not the case. Thus we are sensitive to the analogy of 'living in a body'.

OUR STUDY

Initially we investigated problems associated with low rise residential buildings only. The report we produced was eventually published as "Hazardous Building Materials _ A Guide to the Selection of Alternatives", and from this book I've abstracted one of the sheets - *Roof Insulation* - as a demonstration of our approach.

It became clear very early on in our deliberations that, for example in the case of a well-known deleterious material such as asbestos, it was not good enough to say 'asbestos is bad and must not be used'. The decision would be dependent upon a variety of factors:

1. where is the material positioned in the building?
2. what is the likelihood of damage and release of, in this case, fibres?
3. what is the level of concentration of the material?
4. are the available substitutes technically suitable?
5. are the available substitutes of a reasonable cost? and
6. how safe are the substitutes?

The approach we adopted was first to take a typical situation where a material was being used that was either known to be deleterious or about which questions were being asked. We then listed all other materials likely to be used in this application. To draw technical comparisons between them it was necessary to write a performance specification and, using a relative scale of 1 to 10, we indicated our preference technically.

To communicate to other colleagues in other disciplines we drew small sketches and also outlined the likely causes of materials' degradation in this application.

Problems arose on how to draw comparisons of the risks to health from the various materials which could be used in a specific application since the experts were located in different parts of the UK. It was impossible to use an absolute scale due to lack of scientific data, so a relative scale was used as shown on page 12.

This enabled each specialist to draw comparisons independently and only at the end was it necessary to bring them together to carry out some fine tuning.

At the same time a firm of Quantity Surveyors was employed to cost each individual solution.

Steve and I summarised the findings using guidance notes. Note that I use the term *guidance*, not *recommendations*. The sheets provide data so that those selecting materials can

make their choice taking into account their own, or client's, perception of risk. It is the provision of those data which we consider to be the most important aspect of our work, as it is very difficult for a designer or specifier to obtain these, or similar, data when working under stringent time restrictions.

THE FUTURE

Obviously there is a need to extend the work further, but to continue analysing each material which could be used in every conceivable application in all buildings would be a gigantic piece of work requiring regular updating, so we stood back and tried to reassess the problem.

IS THERE REALLY A PROBLEM WHEN WE CONSIDER ALL BUILDING TYPES?

The answer is yes, but the severity of the problem is uncertain. The dangers associated with the choice of materials and design of buildings are being discussed at this Workshop. These and other problems can be demonstrated from a variety of sources, for example:

(a) The book, *Hazardous Building Materials,* besides confirming the risks associated with asbestos and lead, also indicated cause for concern regarding pentachlorophenol, other chemical volatiles and preservatives.

(b) Diseases associated with 'tight buildings' have been clearly identified. Legionnaire's disease and others associated with air conditioning is well known and increasingly 'building sickness' syndrome is being demonstrated as being a problem.

(c) The significance of radon, in both the ground in certain parts of the UK and in some construction materials, has been shown by the National Radiological Protection Board.

(d) Allergies and sensitivities in some people, it is supposed, are directly related to the material content (including furnishing and fittings) of the building.

(e) The Medical Research Council has identified materials which are extremely dangerous, but has not been able to establish whether they are currently being used in building materials.

(f) The Building Research Establishment has warned about the potential knock-on effects of draughtproofing, which can reduce ventilation to the point where indoor air pollutants reach unhealthy levels. These pollutants include (besides those generated by the occupants) formaldehyde, a material found in many components in residential properties.

As stated above, the severity of the problem has not been quantified and considerable research will be necessary to establish the extent to which concern should be shown.

WHAT ACTION SHOULD BE TAKEN?

It is suggested there are four main ways forward:

(a) Continuation of research into improved means of ventilation and control of the indoor environment, modified as a result of the findings.

(b) Research into levels of indoor pollution and associated health hazards.

(c) Release and publication of the contents of all building materials in current use.

(d) Systematic recording of the quantity and position of known hazardous materials used in our existing building stock.

There is not time today to address all of these so I would like to concentrate on what I believe to be a key mechanism for directing the way further research should take. This is, the

IMPORTANCE OF RELEASING INFORMATION ON THE CONTENTS OF MATERIALS

It is necessary to identify critical materials which give rise to health hazards in practice. This can be established, as indicated previously, by maintaining and collecting data on indoor pollutants, looking at the health effects of different concentration levels of identified pollutants, and collecting and collating data on illness caused by indoor pollution. This is the information which designers want, but which will be a long time coming. It has to be asked whether we can afford to wait so long. The process could be accelerated if at the outset <u>potential</u> critical materials could be identified so that this reseach can be directed. However, it is not clear what the full range of these materials might be (although some are obviously front runners), since it is not known what the make-up of many building materials are and hence what the total quantity of a potential pollutant is likely to be from the summation of all those used in the building.

It is argued that the quickest and hence the most effective way to safeguard building users' health is to work towards obtaining a detailed breakdown of all materials used.

DIRECTION OF HEALTH RESEARCH

As indicated above, data on the contents of materials are required so that scientific research can be directed to where the problems are most likely to occur.

Whilst manufacturers clearly do not wish to be associated with a future scare on the scale of asbestos, what guarantee is there that it will not happen again? Individual products may satisfy health and safety criteria in isolation, but it is the problem of synergism (the cocktail effect) which needs to be addressed. It would be interesting to see how an independent observer, such as the Medical Research Council or the Environmental Safety Group at Harwell, would perceive the cumulative effect of various products in 'tight' buildings, for example. Research of this type may prove there is no problem, but without more information on new and existing materials the results of this type of research lag well behind the extensive deployment of materials in buildings.

Imported materials need to be covered also. Both France and Germany still use blue asbestos in their asbestos cement products. Can we guarantee that none of these products find their way into our buildings?

DESIGN SELECTION OF MATERIALS

"If there is a choice between two materials for a specific application in a building, both of which perform technically well and are of equivalent cost, choose the one which is least toxic".

The above is an apparently simple statement that nobody could disagree with. 'Apparently', because the situation is not quite as simple as it appears owing to uncertainties regarding the definition of the term 'toxic'. For example, is it meant to mean the levels of toxicity of each different component in a material cumulatively totalled irrespective of the real combined effects (the cocktail effect), or is it a measure prior to 'encapsulation' within a component, or a measure of rates of emission from the material?

Clearly, making comparisons in absolute terms is a complex matter because of the wide ranging parameters, but is this an argument for taking no action - surely not. For example, the food industry now clearly defines the contents of its packaging. No explanation is given of the likely cumulative effects of the different components predesignated by the letter E, and yet the public at large has welcomed this clear demonstration.

One of the dangers of secrecy or lack of availability of information is that the wider the gaps in credulity, the greater the span of perception becomes. This is dangerous and leads to unsatisfactory decision making, since the real issues are clouded. The nuclear energy debate is a clear example of this. The CEGB has predicted safety based upon models of the likelihood of failure on components making up the whole, whilst their opponents are using historical data on failure, producing a distinctly different set of figures. The result is confusion with personal prejudices often overruling logic. How difficult it is then for the person wishing to see the truth to find it!

The current problem within the construction industry is that not only do many suppliers not, as a matter of course, detail the contents of materials in, for example, trade literature, but they are often reluctant to furnish it even on request, and designers rarely have the time to analyse what information is provided and indeed are not qualified to understand the health implications. However, when they have a real need for advice in this area, it is very difficult to gain data to give to health advisers for them to provide guidance. For example, when designing a school for ESN children, it seems reasonable to decide (since the children might well chew painted woodwork) that the lead content of all paint used should be below the 600 ppm recommended by the Royal Commission on Environmental Pollution. But the designer will, when specifying gloss paint, with the exception of white, have difficulty achieving this objective. The limited information that is available is primarily due to the pressure exercised by CLEAR on the manufacturers.

Should not information be made available to allow open analysis and free choices to be made? Indeed, does our society have a right to know? The cost of providing the information is insigificant. Manufacturers provide trade literature; they all know the contents and their products; so there should be no problem. The trade secrets argument is not valid; most companies know each other's product composition, often due to the exchange of personnel between companies. More often than not, it is the process that is protected rather than the product composition.

HOW CAN THE RELEASE OF INFORMATION BE ACHIEVED?

The current position is that the British Standards Institution committees have an obligation to take cognisance of the fact that a material may have a risk, but are not required to take account of the 'cocktail' effect. The HSE receives information from manufacturers but only from those involved in making or processing the material and products.

There seems to be four possible ways forward:

(a) independent testing paid for by interested parties who in

turn publish their findings;
(b) statutory regulations;
(c) voluntary agreements or codes of practice; and,
(d) consumer pressure.

(a) **Independent Testing**
This is a difficult area, although in principle it is desirable to have testing procedures and standards. It should be possible to derive quick reacting tests on materials, but the problem, when armed with this information, is how to assess health risks so that acceptable standards can be set?

This is a new area of work. Previously, most knowledge derives from toxicological or epidemiological research. Standards are then set, based upon medical opinion and judgement at a point in time. This can, of course, vary in the light of future knowledge, but is at least a starting point. However, what of the large number of materials about which little is known? The problem is enormous and the subsequent costs potentially prohibitive. It may be more sensible, therefore, not to follow this line of research, but simply to publish results of physical and chemical testing, allowing opinion as to whether or not to use the material to be determined by free choice or observations made by independent bodies.

Testing, however, is complicated if done independently, since a manufacturer may change the formulation without changing the trade name. This would be difficult to pick up in practice and could cause the published figures to lose credibility.

The topic is complicated further, as in all approaches, by the number of air changes likely to occur. Whilst not wishing to belabour the point, it should be remembered that this affects all judgements made regarding hazardous materials and the effects on occupants but it is especially crucial if trying to provide scientific standards rather than making educated and informed, but nonetheless subjective, judgements.

(b) **Statutory Regulations**
At a time when central government is trying to

deregulate there are inevitably problems in flowing against the tide. Whilst in many respects the 'neatest' solution on the surface, it is probably most unlikely that government would move in the direction of statutory regulations. These would inevitably take a long time to effect, in any case. The matter is further confused at the present time, as the only clear evidence for a total ban by regulation approach is for asbestos and lead. Additionally, as soon as regulations are put into force, a battery of experts appear to find ways round them.

(c) **Voluntary Agreement**
What incentive does a manufacturer have to declare the contents of his product, especially if a toxic material is included, however innocuous when incorporated within the component? His fear, understandably, is that if he is open and others are not, then his market share may come under attack. To ensure that voluntary agreement or codes of practice are to take place, then manufacturers in specific product areas (eg asbestos fibre replacement materials) must be persuaded to co-operate in turn. This again seems fraught with difficulty and again could take a very long time. However, voluntary procedures are known in other fields and have had some degree of success.

(d) **Consumer Pressure**
This divides into two distinct camps. Firstly, the knowledgeable client such as the British Property Federation, the Property Services Agency and Local Authorities, and, secondly, the mass consumer, eg the house purchaser and their protective organisations such as the Consumers' Association. The strength of the Consumers' Association tends to be a function of the quality of the people within a particular section. To date they have shown little interest in the potential problems of housing, so whilst this must eventually be a sound route, it will take time. This leaves the former group - the knowledgeable clients. Concern has already been shown by several sections in this group and for obvious reasons, ie that it could cost them a lot of money if they were to 'get it wrong'. That is not to say that they are only open to financial pressures; this would be a totally unfair assessment of attitude. If this

group could be persuaded to act, then probably a snowball effect would be triggered which would more rapidly develop a major trend in the right direction. If this group demanded disclosure of information, the manufacturers would have little alternative but to comply unless they acted together and resisted in unison. This is unlikely for two reasons. First, with current commercial pressures one company is bound to break ranks especially if their product is 'the safest' and, secondly, the fear of media pressure as to what they had to hide would also act as a good stimulant for acceptance of the request.

It is, of course, an expected development that if pressure arises from this source, effectively a voluntary regulation procedure would follow. If, on the other hand, the Consumers' Association became involved, resulting pressure could further force either voluntary or statutory control. In many ways, this might be the best role for regulation, ie forcing manufacturers to disclose information as presently happens in the food industry.

Whatever system might be adopted, it will be important to devise a method of policing. This has not been addressed here as it is outside the writer's field of experience.

DEVELOPMENTS

Since publication of the book, *Hazardous Building Materials*, last year, to our delight almost without exception reviewers have commended the way the information has been presented for easy interpretation and clearly identified the importance and use of having such information available. The book, however, only scratches the surface.

Positive steps have been taken. The British Standards Institution (BSI) has agreed to bring the book's existence to the attention of all secretaries of relevant BSI committees. The National Building Specification have asked for recommendations to be made for them to incorporate into their specifications as and when they revise them (it takes approximately 3 years for the revision cycle to be completed).

On the other hand, the British Board of Agrément, whilst agreeing in principle that the ideas were sound, had to admit that since they rely for business on the goodwill of manufacturers, they could in no way insist that appropriate data was made available on their certificates. However, it was felt that once the major suppliers began to do it, others would follow suit.

CONCLUSIONS

(a) Research needs to be continued and promoted in all areas associated with health risk to occupants of buildings.

(b) Since the range of work is so vast, that research needs to be directed to key areas.

(c) This direction will be assisted considerably if the contents of all materials are made readily available.

(d) The customer of buildings needs to be made more aware of likely problems and encouraged to take an active part in promoting safer buildings.

REFERENCE

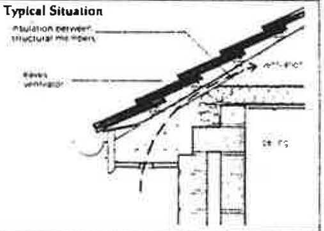
Hazardous Building Materials - A Guide to the Selection of Alternatives (1986). Edited by S.R. Curwell and C.G. March. Published by E. & F.N. Spon Ltd, price £16.00 (hardback) or £6.95 (paperback).

	Potential hazard when in position	Potential hazard when chance of being disturbed	Long-term potential environmental hazard in waste disposal
	A	B	C
None reasonably foreseeable	0	0	0
Slight/not yet qualified by research	1	1	1
Moderate	2	2	2
Unacceptable	3	3	3

Application 7.8

ROOF INSULATION

Typical Situation



Technical Requirements

Rot proof insulation for laying over ceiling between joists to provide overall minimum roof 'U' value of 0.35 W/m²°C. Water resistance and non-combustibility an advantage. Must be dimensionally stable.

Decay and Degradation Factors

Wild life. Interstitial condensation. Fire. Contact with occupants every time access made into roof space. Dust turbulence due to effective ventilation required to prevent condensation. Contamination of water supply via uncovered water storage tank by dust particles and fibres.

Guidance Notes

The choice between the alternatives depends upon the importance ascribed to non-combustibility of the insulation, but this is not mandatory in the domestic situation.

Some samples of vermiculite have been found to contain asbestiform fibres which is a cause for concern with this material. It should only be specified when manufacturers/suppliers can show that the material does not contain respirable fibres especially the very fine fibres below 0.3 um in diameter. Specifiers should note that electron microscopy is necessary to test for this.

Loose fill granular/bead types have a small advantage due to the relative ease of installation in the confined spaces of loft areas, but this is offset by the risk of the sand dune effect due to the ventilation required for condensation control.

It is essential to seal all holes/ducts entering the roof space from the interior to prevent loss of loose fill, fibres etc and also to reduce ingress to the habitable spaces. It should be noted that none of the common applications can be described as having no risk. Although the risk rating for mineral fibre represents only a suspicion, this has to be balanced against the hazard in the event of fire from the main alternatives.

Alternatives	Technical Comment	Rank	Health Comment	Rank	Cost Comment	Unit	Rate £s	Quantity per dwelling	Total cost per dwelling £s
1 Mineral wool quilt	Non-combustible. Material compacts over time thereby reducing insulation value.	1	Slight fibre release during access to loft maintenance. DIY and via structural gaps.	0/1/1	100 mm quilt.	m²	3.75	40m²	150.00
2 Loose mineral fibre		1	Roof ventilation also a factor in potential exposure. Skin, eye and throat irritation possible. Essential to avoid contamination of water systems. Long-term risks from fine fibres unlikely but not yet fully determined.	0/1/1	100 mm loose fill.	m²	1.75	40m²	70.00
3 Cellulose fibre	Must have insecticidal and fungicidal protection for long-term durability. Combustible. Available with various fire properties.	2	Fibre toxicity not ascertained. Dust may enter living areas. Insecticides and fungicides may present hazard.	1/1/1	100 mm blown.	m²	3.75	40m²	150.00
4 Polystyrene beads	Sand dune effect from strong air movement in roof space. Slight reaction with PVC sheathed cables. Combustible. Available with various fire properties.	2	No health hazard foreseen except in event of fire.	0/2/0	100 mm loose fill	m²	2.75	40m²	110.00
5 Polyurethane granules	Sand dune effect less of a problem due to shape of granules. Combustible. Available with various fire properties.	2	Slight risk of sensitization. Additional health hazard if involved in fire.	1/2/0	100 mm loose fill.	m²	4.10	40m²	164.00
6 Vermiculite	Can absorb moisture, lowering insulation property. Poor level of insulation for similar thickness of alternative material. Sand dune effect from strong air movement in roof space. Non-combustible.	3	If asbestiform fibrous dust involved then hazardous. If it can be shown after examination using electron microscopy that there are no such fibres the rating would be 0/0/0.	3/3/3	100 mm loose fill.	m²	3.75	40m²	150.00

TABLE 1 - Summary of the epidemiological studies of risk of lung cancer in non-smokers associated with exposure to environmental tobacco smoke

Authors	Study location	Sex	Exposed to environmental smoke: Lung cancer	Exposed to environmental smoke: No lung cancer	Unexposed to environmental smoke: Lung cancer	Unexposed to environmental smoke: No lung cancer	Relative Risk*	95% Confidence limits	
				Case-control studies					
Chan and Fung	Hong Kong	F	34	66	50	73	0.75	0.43	1.31
Correa et al	US	F	14	61	8	72	2.03	0.81	5.08
		M	2	26	6	154	2.29	0.30	17.33
Trichopoulos et al	Greece	F	38	81	24	109	2.11	1.17	3.78
Buffler et al	US	F	33	164	8	32	0.80	0.32	1.99
		M	5	56	6	34	0.50	0.14	1.83
Kabat and Wynder	US	F	13	15	11	10	0.79	0.25	2.48
		M	5	5	7	7	1.00	0.20	5.06
Garfinkel et al	US	F	91	254	43	148	1.23	0.81	1.86
Akiba et al	Japan	F	73	188	21	82	1.48	0.87	2.52
		M	3	9	16	101	2.45	0.45	13.45
Lee et al	England	F	22	45	10	21	1.03	0.41	2.58
		M	8	14	7	16	1.30	0.37	4.54
Koo et al	Hong Kong	F	51	66	35	70	1.54	0.89	2.67
Pershagen et al	Sweden	F	33	150	34	197	1.27	0.75	2.18
Values overall for case-control studies			425		286		1.27	1.05	1.53
				Prospective studies					
Garfinkel	US	F	88	127 164	65	49 422	1.18	0.90	1.54
Gillis et al	Scotland	F	6	1 388	2	521	1.00	0.20	4.91
		M	4	306	2	515	3.25	0.60	17.65
Hirayama et al	Japan	F	146	63 287	37	21 858	1.63	1.25	2.11
		M	7	1 003	57	19 222	2.25	1.04	4.86
Values overall for prospective studies			251		163		1.44	1.20	1.72
Values overall for all studies			676		449		1.35	1.19	1.54

nsca

1987 WORKSHOP
25-26 MARCH
MANCHESTER

INDOOR AIR QUALITY
ACCEPTABLE STANDARDS AND BUILDING DESIGN

POLLUTION FROM AIRBORNE METALS

by
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I want to consider indoor air quality in relation to metals. When I originally looked at this question, I was struck immediately by the scarcity of data. There is an abundance of data from measurements of metals in drinking water and measurements of metals in the outside atmosphere, but, in relation to indoor air, very few data indeed. Much of the information I shall present is by inference rather than direct measurement. One of the problems encountered in the Study Group on Buildings and Health co-ordinated by Chris March and Steve Curwell was that we really had very little hard data on which to base our estimations of hazard.

Looking at some of the toxic metals which turn up in the home, it is necessary to consider not only building materials but furnishings as well; these can be quite important. First I shall give an indication - a subjective, non-expert indication - of human toxicity.

I think most of us will agree that **lead** can be substantially toxic to humans. In the home it can be used in leaded lights, it turns up in old paint - a subject I shall consider later on - and in pipes. Leaded lights and pipes are I think very unlikely to give rise to significant airborne concentrations of lead or deposited leaded dust, whereas, as we shall see later, the old paint may be of some significance.

Cadmium is not used appreciably in any building materials but does turn up in the rubber backing on carpets, in association with zinc. Zinc oxide is used as a filler in the rubber, cadmium is an impurity in the technical grade zinc oxide used and elevations of cadmium in household dust have been observed because of this.

Copper, used in pipework, tends to be considered amongst

the toxic metals, but from the point of view of human toxicity this is not so. Copper is substantially toxic to aquatic organisms;
so too is **zinc**, which again is not a problem in terms of human toxicity. If anything, we are probably a bit zinc deficient. Zinc is used in the home or in buildings, in galvanised iron, in ducting for instance, as well as in the rubber backing for carpets.

Chromium, used in stainless steel, is certainly toxic in the hexavalent state. **Nickel** can also turn up in some stainless steel. I do not know too much about the toxicity of nickel, other than in the pentacarbonyl form, which certainly should not turn up in buildings. But stainless steel, because of its nature as a corrosion-resistant material, is unlikely to give rise to any substantial amount of these metals in dusts or in suspended particles.

Aluminium, until recently considered essentially non-toxic to humans, is now under suspicion since conditions like dialysis dementia came to light and possible links with Alzheimers Disease. However, despite its use in cooking utensils in the home there is not much scope for its presence in surface dusts or in airborne materials in concentrations any higher than those out of doors, which arise simply from windblown soil etc. I think aluminium is unlikely to be a problem.

Thallium, beryllium and mercury are probably more toxic elements than any of those discussed previously but are not expected to be used appreciably in the home, with the exception perhaps of a very small amount of mercury in thermometers!

Looking at elevated concentrations of cadmium in surface household dusts, these are about 5-20 micrograms per gram compared to about 0.3 micrograms per gram typical in soils; cadmium is not as far as I know appreciably elevated in indoor air. The particles are quite large, so do not become airborne very readily. Elevated concentrations of lead in household dusts, in surface dusts, are due to multiple sources. Because there has been so much more research on lead than on any other toxic metal, most of my discussion will relate to data on lead, because it is really the only metal on which we have very much data.

I want to discuss lead in terms of some of the processes which are likely to be important in influencing concentrations of lead in the air inside a building. I should credit Ron Hamilton of Middlesex Polytechnic for much of this work. He has produced a useful diagram to explain transport pathways for lead in the indoor environment, and indeed it would apply to other metals. Given an airborne source of lead outside the home, there is transfer of air both into the building from outside and inevitably from the inside to outside the building in air exchange. There is transfer of lead from the air to surface dusts in a deposition pathway, and the possibility of resuspension of surface dusts, so that they become airborne, thus increasing the airborne concentration of lead or any other metal involved.

Outside dusts can be transported into the home without becoming airborne. About 10 years ago, when we first started looking at household dusts under a microscope, I was surprised to find how much of the dust appeared to be soil-derived. As we come in with muddy shoes we bring dust into the house purely by transport on shoes, something very poorly quantified as a pathway but undoubtedly quite significant for bringing dust into the house. Within the house there is the deposition pathway of fallout of lead particles from the air into the surface dust and also the possibility of dust resuspension. I shall look at these pathways and the little that is known about the quantification of them later.

In terms of quantification, it is useful to give some indication of what are typical hot spot levels of lead in our environmental medium. Taking a typical air lead level of 0.2 micrograms per cubic metre and a hot spot level of 5 micrograms per cubic metre in air, that can be compared with a US EPA standard of 1.5 micrograms per cubic metre, an EEC standard of 2 micrograms per cubic metre and an 8 hour working day standard for industry of 150 micrograms per cubic metre (under medical supervision of course). In dusts, surface loading of lead might be typically 600 micrograms per square metre of surface, with up to 30,000 ug/m2 in a hot spot area, such as might be associated with a geochemical anomaly or with very high local industrial emissions of lead.

Concentrations in particulate matter are typically about 1% by mass of airborne particles in this country, perhaps less now since the reduction of lead in gasoline in 1986 - with a hotspot figure of 5%; and looking at the typical level of lead in surface dusts - roughly 600 micrograms per gram, with 30,000 micrograms per gram at a hotspot; that represents 3% by weight in hot spot areas and indeed much more than that in some locations. These relate to the total solids concentrations, which are linked with typical surface dust loadings of about 1 gram per square metre.

There will be more in some homes than in others; indeed the internal dustiness of a building is a very important factor in the contribution of surface dust to airborne dust.

There have been several studies of indoor/outdoor relationships of lead in air. The ratios are clearly dependent on factors such as the air exchange rate between the inside and outside of the building, but generally there is less lead in air inside the building than outside, which suggests the existence of effective removal mechanisms in the home and restricted air exchange between indoors and outdoors. Studies carried out to date, showing ratios of between 0.42 and 0.98, have been carried out in rooms which have not had much human activity in them, so the results may not be very realistic. It is a subject which warrants rather more research.

Turning to lead in surface dusts, ie the sort of surface dusts which can be carefully swept up from the floor or the pavement, and which are typical of house dusts - we see concentrations of about 600-1,000 micrograms of lead per gram in house dust, rather less than in street dust. Only one study showed more lead in dust within the house than in the street. Many factors can influence this ratio. There is no good reason why there <u>should</u> be more lead in dust outside than inside. If we recall the pathways, we can see that there are mechanisms of transfer of surface dust between the inside and the outside which would tend to equalise the concentrations. And while there are sources of lead, industrial and also automotive, in the air outside, we also have sources inside the home, particularly, old paint. I'm sure there will be a significant number of homes where lead in dust <u>inside</u> is in concentrations appreciably higher than

outside, and I think that is generally due to a paint source.

There have been few actual measurements of lead loading, in micrograms per square meter, either inside or outside the house; generally dust loadings are a little less inside than outside. The availability of lead for suspension into the air will be a function of the loading - the amount per unit area of surface. Generally surfaces inside a building are cleaner than those outside, although this is not universally so.

Looking at some of the pathways, the deposition processes, these can be quantified in terms of a deposition velocity, which is the ratio of the deposition flux - the amount of material (in micrograms) depositing per unit surface area, per unit time - divided by the atmospheric concentration. It is a measure of the efficiency of deposition. In the Arnhem Lead Study, measurements were made of deposition velocity outdoors and indoors and an abnormally high deposition velocity was found outdoors, almost two orders of magnitude higher than indoors. There are factors relating to particle size, distribution of the airborne lead, wind speeds and meteorological factors which mean that lead deposits more effectively outdoors than indoors. Since indoor concentrations of lead in air are less than outdoor concentrations, since the deposition velocity of lead indoors is less than outdoors, deposition of lead inside the building will typically be less effective than outside.

However, resuspension is a much more interesting process from the point of view of concentrations inside a building. suspension is very poorly quantified. There two descriptive parameters; one is the re-suspension rate, with units of either $(\text{events})^{-1}$ or $(\text{time})^{-1}$, which gives the fraction of dust resuspended per resuspending incident event, or the fraction of dust resuspended per unit time. Given 1000 micrograms of lead per square metre of surface in each resuspending event, which might be a gust of wind or someone stamping on the leaded dust, and given that 1 microgram is resuspended, then the resuspended fraction is 10^{-3} or 1 in 1000. The resuspension factor is the atmospheric concentration due to resuspension divided by the surface loading, which involves dividing micrograms per cubic meter, resulting in units of meters^{-1}.

Values are recorded in the literature, very small numbers by and large, and if we use the values for resuspension factor, we can think about how they apply to typical outdoor activities - I call wind an activity in this sense - with, indoors, walking and sweeping. Walking is quite a vigorous activity; walking on a carpet will certainly resuspend dust. Sweeping is a dreadfully vigorous activity from the point of view of resuspension, much more effective than wind. Indoors, even at typical lead loadings, they can be quite a significant contributor to lead in air particularly sweeping. In hot spot areas they can be very important - with a resuspension-induced concentration of up to 300 micrograms per cubic meter. It is worth bearing in mind, however, that sweeping is not a continual activity in most homes, so it will produce a rather short-lived elevation in concentration; its long term influence is very difficult to quantify. I suspect that in studies of indoor/outdoor relationships, activities like sweeping have been very definitely avoided during the measurement of indoor lead levels.

High levels of activity in the home, for instance associated with children, could cause appreciable levels of lead in air but its significance as an exposure pathway, and indeed the relative importance of the hand to mouth pathway - ie hand in dust, hand in mouth - is not well quantified. The statistical studies indicate that there are fairly definite relationships between lead in dust and lead in blood for children and that dust can be a significant contributor to lead in blood for children. What we do not know is how much of that lead is getting in through the resuspension inhalation pathway and how much via the hand-to- mouth activity pathway.

Moving on to the rather horrendous practice of stripping old paint, I found in the literature a paper by Inskip and Atterbury from the Heavy Metals Conference in Heidelberg in 1983. They had done experiments, both in a fairly confined space and what they described as <u>in situ</u>, which was simply inside a fairly normal house, where the lead in paint was about 10% to 40% dry weight. It is not at all uncommon, in old paint, that the lead is so abundant. The researchers stripped the paint with a propane gas burner, with a hot air gun, and by sanding, and presented their results in micrograms per cubic meter of, lead in air. All

the measurements were very high but the sanding process produced absolutely astronomic levels. Only a very small percentage of the particulate lead coming from sanding - about 1% to 3% - was less than 2 micrometers aerodynamic diameter and therefore likely to be respirable as far as alveolar absorption is concerned, although the workers did not define the distribution in the range where there might have been tracheobronchial deposition and then elevation and swallowing in to the gastro-intestinal tract. Even so, at only 1% to 3% of the total, the lead available for absorption would still be about 200-600 micrograms per cubic meter, so that even short term exposure (and one would hope it would be short term during this sort of activity) could make a massive contribution to exposure to lead and indeed to any other metal that might be in the paint. There are cadmium pigments in paint, although it is argued that they are of very low solubility and therefore not a very important pathway of exposure. In the same study, lead in house dust (in surface dust) was measured, in one case immediately after paint removal, and dust lead was in the range 5000-100,000 micrograms per gram, ie very highly elevated. After completion of recent restorative work, using sanding, that level had declined appreciably and in a comparable house with no recent restorative work, levels were found to be still elevated but not nearly as high as where the restorative work had been carried out.

My own research group has looked at the contribution of paint flakes to lead in household dust, in houses where recent paint stripping had <u>not</u> taken place. Dusts were collected, and sieved into a range of fractions. This was done for street dusts and household dusts. Some of the dusts were collected from Leeds. The contribution of paint lead to total lead in dust was up to 15% - with other samples being 5%, 12%, and 0.9%. However, the lead in paint levels were generally fairly low - only up to 3% at highest. Given that there could well be ten or more times more lead than that in some paints, then we could be seeing fairly massive contributions of paint to lead in household surface dusts in some households. We did measure size distributions and I suspect that that paint-derived lead, coming from normal attrition of paintwork, will not be very readily resuspended, because the flakes are too large, so it may not be an important source of lead in air.

In conclusion, I believe that, in looking at levels of metal in air in houses, further experimental measurements are required but we must not think that the only source is metal coming from outside. The pathways, particularly involving resuspension, need very much more active research.

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INDOOR AIR QUALITY
ACCEPTABLE STANDARDS AND BUILDING DESIGN

PERCEPTION OF AND REACTION TO NOISE

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1.0 INTRODUCTION

1.1

The harmful or potentially harmful effects of many indoor pollutants are relatively clearcut. Except at the very high sound pressure levels associated with industrial processes, this is not the case for indoor noise pollution. This is because many types of noise as heard indoors have no proven effects on the physiological health of the individual but cause dissatisfaction through activity interference or undesired intrusion into the individual's perceptual world. Activity interference can occur whenever the individual is engaged in any directly noise sensitive task such as listening to speech or music or where an individual requires relative silence to assist in concentration or dropping off to sleep. The type of undesired intrusion caused by a thoughtless neighbour's TV, hi-fi system or violin practice can cause considerable interference with rest and relaxation even at extremely low noise levels.

Nevertheless, some environments can be perceived as being "too quiet" by some individuals, indicating that a certain amount of noise can be a good thing in some applications. A particular example of this is railway terminus background music which, however much the particular programme may not appeal to individual taste, has definite advantages in reducing overall stress levels in the probably belated commuter crowds. Even in the industrial situation, there has been some resistance to the wearing of recommended hearing protection devices on the grounds of allegedly interfering with the perception of subtle acoustical cues as to the satisfactory progress of industrial processes or with the perception of warning sounds. Thus it can be seen that whereas a certain amount of sound is always present in any community or human undertaking, the precise point at which a sound becomes unwanted, and thus a noise, is very dependent both on the nature of the source, and on the situation of the exposed individual. Despite the investment of considerable resources in noise research during the past 30 years there are still large areas where our knowledge is very limited as a result of the complexity of the problems involved.

2.0 NOISE EFFECTS

2.1 Noise Levels

In general, noise does not damage buildings, except in specific circumstances such as sonic boom and structural resonances excited by noise from sources such as artillery ranges or heavy vehicles passing over damaged road surfaces. This is because even very loud noises have minimal acoustical power. A sound pressure level of 194 dB corresponds to an acoustic pressure of one atmosphere (fifteen pounds per square inch or 10^5 Newtons per square metre). A typical conversational maximum sound pressure level of 74 dB corresponds to an acoustic pressure of one millionth of this, or fifteen millionths of one pound per square inch. The faintest sounds that can be heard have an acoustic pressure of one five thousandth of the speech sound at 74 dB SPL. Thus it can be seen that the human ear is exceedingly sensitive and correspondingly vulnerable to acoustic pressures that would produce insignificant displacements in typical building structures.

2.2 Noise Induced Hearing Loss

The UK Code of Practice for reducing the exposure of employed persons to noise specifies a limit of an equivalent continuous sound level of 90 dB(A) as averaged over an eight-hour day, with higher levels for shorter exposure periods. Noise induced hearing loss is a well-documented occupational risk for workers in higher continuous noise levels, with a significant occurrence of disability even at lower exposure levels. There are currently moves to reduce the 90 dB(A) L_{Aeq} (8 hour) exposure limit to take account of this remaining risk as cost-effective noise control technology is developed. Short-term exposure to higher noise levels can cause a temporary threshold shift (TTS), characterised by a sensation of "ringing in the ears". While full sensitivity and discrimination normally return after TTS there is some evidense from animal studies that even TTS could be associated with permanent damage to the inner ear. The precise damage mechanisms are not fully understood, owing at least in part to the inaccessibility of the inner ear

structures to histological examination without causing major disruption.

2.3

Very high acoustic pressures can cause immediate rupture of the ear drum or physical damage to the middle and inner ear structures, although the likelihood of damage is dependent on the individual concerned. The threshold of rapidly occurring mechanical damage is thought to be around 150 dB SPL, a level which can easily be exceeded in the vicinity of small arms, artillery and pyrotechnics. High level transient sound can often be deceptive as the ear exhibits a finite integration time in terms of the development of loudness. Thus transient sounds associated with explosives might not sound as loud as a continuous sound at the same level would be despite having a similar potential for causing acoustic trauma. Such high sound pressure levels are extremely rare in buildings.

2.4 Physiological Responses

Whilst excessive industrial noise exposure and the costs of appropriate control measures remain serious problems for a small percentage of society, general exposure to everyday noise can make a significant contribution to disamenity in many ways. There is much interest in the effects of noise in terms of physiological response, particularly in Europe. Unexpected noise or an expected noise occurring at an unpredictable time can elicit an orienting or a startle response with associated effects on the autonomic system. Cardiovascular, respiratory, pupil dilation, skin resistance and hormonal responses have all been measured in response to such stimuli. Whilst some workers believe that these responses could be precursors of disease it is not known whether there is in fact any cause and effect relationship. Autonomic system responses to sensory stimulation are a necessary part of behavioural responses to environmental situations in terms of gathering more information or preparing for action. Nevertheless, they indicate that noise can be considered as a stressor with the associated theoretical consequences of a perceived lack of control of the noise source by the exposed individual where the noise source makes an uncontrolled intrusion.

2.5 Speech Interference

Whilst it is meaningless to rank order the sensory modalities in order of importance to the individual, it is certain that the sense of hearing provides considerable information to the individual in terms of being able to construct a perception of their external environment and in terms of being able to communicate with others. The sense of vision is highly selective in that the individual can avoid overstimulation due to complex visual fields by directing his gaze. This is not possible in respect of the sense of hearing. Speech communication can be surprisingly resistant to the effects of interfering noise or other distortions, primarily due to the powerful ear and brain mechanisms which have evolved to extract the required information and to the contextural redundancy present in normal speech. For example, speech babble produced by recording multiple talkers simultaneously can be very distracting in terms of the intelligibility of an experimentally presented word list, but it can be made to be much less distracting if the speech babble and experimental word list are presented separately to the left and right ears using headphones. This is an example of an experimentally contrived assistance to the ear and brain selectivity mechanism which could not normally be applied under everyday circumstances.

2.6

Thus speech communication can be disrupted by intruding noise which either masks the relevant speech components so that they cannot be distinguished from the background noise, or confuses the ear and brain speech reception mechanisms as in the case of interfering speech babble. These types of interference can apply to conversation, use of the telephone, TV and radio listening, and public address in auditoria or large public spaces. The masking effects of background noise in different frequency bands are relatively easy to predict by using the well known Articulation Index or similar more recent techniques such as the Dutch Speech Transmission Index but these methods based on a weighted sum of signal to noise ratio in different frequency bands do not account very well for more complex forms of signal degradation and make no allowance for intermittent

interference, or differing amounts of contextural redundancy in the speech.

2.7 Sleep Interference

Sleep can be considered as another "task" which is sensitive to interference by intruding noise. Here research has traditionally divided into two main streams. First, physiological scientists have conducted many experiments with instrumented sleeping volunteer experimental subjects both in the laboratory and in their own homes. They have discovered that intruding noises can cause premature changes in sleep stage so that individuals might spend less time in the deeper sleep stages during the night. Second, social statisticians have explored the relationships between reported sleep disturbance as measured using social survey interview techniques and noise exposure as measured or predicted by acousticians. There tends to be rather poor correlation between reported awakenings and historical records of intrusive events such as aircraft flyover noises and, similarly, rather poor correlations between reported sleep quality and observed behavioural awakening or sleep stage change patterns. However, it is possible to infer that intrusive noise does not affect sleep at all at indoor levels below about 35 dB(A) and also that reported sleep disturbance is not significantly increased by aircraft noise, for example, until the exterior noise levels exceed approximately 82 dB(A).

2.8

These remarks on sleep disturbance must be qualified by specific reference to the particular sensitivity of some individuals to recognisable noises during the process of dropping off to sleep. This phenomenon is more likely to be due to the distracting effect of the information content of the sound than any simple relationship between noise level and arousal level. However, this does not mean that this effect should be discounted when making a practical assessment of a reported noise problem.

2.9 Task Interference

Other tasks do not appear to be directly affected by noise if there is no requirement for the assimilation of acoustic information and the noise does not possess a high information content. Thus mental arithmetic and similar tasks are not affected by bland continuous noise at even relatively high levels, whereas a sound with some information content, ie. by being speech-like in some way, can be considerably distracting. An experienced machine operator might be perfectly able to solve crossword puzzles in the presence of relatively high noise levels for his machine, yet will rapidly be alerted from his crossword puzzle solving task in the event of an unusual sound indicating a fault or hold-up of some kind. This effect can be used to advantage by adding an artificial background noise from heating and ventilating plant or even loudspeakers to ensure conversational privacy between adjacent sections of an open plan office. This not only assists information security but also allows adjacent staff to work without the continued distraction of partially overhearing other conversations which may or may not be relevant to them.

2.10 Health Effects

Other than noise induced hearing loss, there is not yet any conclusive evidence for any general adverse effects of noise on health. Limited studies suggesting increased rates of foetal abnormality and cardiovascular disease near certain American airports were not properly controlled for the many other socio-economic and environmental factors that could have influenced the observed morbidity. From the viewpoint of the epidemiologist, different individual noise exposure levels can be extremely difficult to estimate merely on the basis of noise contours derived from acoustical prediction and sample measurements. Individual noise exposure depends not only on the place of residence but also on the workplace, on travel, on social activities and on the way in which the dwelling is occupied. These measurement errors can seriously affect the accuracy of social surveys on reported environmental quality but they are likely to completely swamp statistical relationships which might be found between low likelihood population responses and poorly estimated individual noise exposure. The West London survey on aircraft noise and the prevalence of psychiatric disorders did not find a consistently greater number of chronic symptoms or a greater use of health services in the higher aircraft noise exposure areas despite a follow up study showing

increased skin conductance responsivity could in isolation have been taken as a result implying potential damage to health.

Subjective Impressions

Noise effects can be classified into those effects that can be measured objectively, such as noise induced hearing loss, a drop in performance levels achieved at some task such as listening to word lists, or an increased number of behavioural wakenings during a sleep period; and into those effects that can only be measured subjectively by the use of questionnaires or psychological scaling techniques. In many circumstances the suitability of any indoor noise environment for its intended purpose will depend upon subjective impressions of the relative importance of the different objectively measurable noise effects that might occur and hence the relative weightings that should be applied in order to aggregate together an overall rating or figure-of-merit. Subjective impressions of an indoor noise environment can be presumed to take account of these weightings as they apply to an individual or a representative group. The research worker's task is then to attempt to tease out the underlying relationships from a study of the physical qualities of the indoor noise environment and the relevant subjective impressions.

3.2

The problem with measuring subjective impressions is that they are dependent upon individual attitudes and a certain amount of measurement bias. To take the example of aircraft noise, there have been many surveys of community response to aircraft flyover noise in the vicinity of major airports both in this country and abroad. These studies have indicated a generally increasing level of mean reported annoyance or dissatisfaction with increases in aircraft noise exposure but the data require a political or administrative interpretation before they can be used for the purpose of setting aircraft noise exposure criteria. This is because the statistical spread in the data due to attitudinal differences between individuals and due to measurement errors and bias would make any discontinuity in the aircraft noise exposure-dissatisfaction response relationship hard to detect even if it existed. A discontinuity would imply a sudden increase in dissatisfaction at a particular aircraft noise exposure threshold which could be used for setting exposure criteria. In addition, aircraft noise dissatisfaction surveys cannot introduce the concept of the costs of noise control on the grounds of potentially biasing the respondents in the airport's favour. The respondents' dissatisfaction scores are therefore made in isolation and require interpretation if they are to be used in any absolute sense. For example, a score of five on an aircraft noise dissatisfaction scale of from zero to nine does not necessarily mean the same degree of actual nuisance as a similar score in respect of some other nuisance.

3.3 Perceptual Constancy

To take the example of aircraft noise exposure further, there is some evidence that dissatisfaction scores are based, at least in part, on subjective impressions of the magnitude of the noise source in addition to subjective impressions of the absolute noise level indoors. Thus a particular aircraft noise could be rated as highly annoying even at a relatively low noise level indoors because it is perceived as being a particularly powerful noise source to produce significant noise levels from a relatively large distance in comparison to nearby road vehicles. This effect is based on the psychological concept of perceptual constancy whereby the individual tends to construct a stable perception of his exterior environment from the varying sensory cues available to him. Thus a listener indoors may partially compensate for assumed facade attenuation when rating the noise of an aircraft or road vehicle passing outside. Owing to the relative distances involved this effect could tend to bias aircraft noise dissatisfaction scores upwards in comparison to road vehicle noise dissatisfaction scores. In addition, it could reduce the apparent benefit of various noise control measures in comparison to that expected from the exposure/response relationships found across the community as a whole.

3.4 Halo and Expectation Effects

The halo effect is another potential bias on dissatisfaction scores. This effect refers to the tendency of subjective

judgements to be influenced by other, at first sight, irrelevant attitudes towards the noise source or sources. For example, residents near to an airport who are connected with the airport in some way through employment or business might be expected to report less dissatisfaction with aircraft noise. In addition there are other subjective expectation effects. This refers to the tendency of subjective judgements to be influenced by the normal range of noise levels associated with any particular noise stimulus. For example, respondents interviewed during a period of relative inactivity due perhaps to an unusual traffic pattern or runway use pattern might report low dissatisfaction scores in comparison against their normal exposure level and not in relation to any absolute interpretation of the dissatisfaction scale.

3.5 Intermittent and Continuous Noise

Comparisons between dissatisfaction scores for intermittent and continuous noises may be confounded by the extent to which respondents integrate their experience of the intermittent noise when forming an opinion. For example, dissatisfaction scores for aircraft noise may refer to the level of intrusion felt at the time that an aircraft flyover occurs and not to the presumably lower level of dissatisfaction which might reasonably be expected to occur if a limited number of aircraft flyovers are integrated over the whole day. This effect could contribute to the well known higher reported dissatisfaction scores for aircraft noise than for a more continuous noise such as road traffic at the same average noise levels (L_{Aeq}), at least over the range of noise levels where exposure to either noise source can overlap. The standard dissatisfaction rating scales for the major aircraft noise surveys in the UK are filtered by an activity inteference check list ("Do aircraft ever ....?") followed by an event specific questionnaire item ("When the aircraft .... how annoyed do you feel?"). This hypothesis is further reinforced by other apparent discrepancies between total noise dissatisfaction and source specific noise dissatisfaction where the source specific response scores can often be greater than the total response scores in the case of intermittent noise sources present against a continuous background noise. This hypothesis adds to the difficulty of interpretation of studies of multiple noise source environments whereas the majority of noise studies in the literature have concentrated on single noise sources even to the extent of ignoring other noise sources that were undoubtedly present, possibly at higher exposure levels than those due to the noise source under investigation.

3.6 Static and Dynamic Exposure-Response Relationships

Field studies of community response to noise exposure are open to many new sources of bias unless they are restricted to a near instantaneous sampling plan across a range of noise exposure conditions at different community locations. This type of study can be used to establish a static exposure-response relationship across a community as a whole under static conditions that does not predict how any section of the community will react to dynamic changes in noise exposure level. Provided that it is otherwise unbiased and accurate, the static exposure-response relationship can only be used to infer the potential long term dissatisfaction of any newly exposed section of the community without reference to the likely influence that that new community's previous experiences of noise exposure will produce. In practice, a newly noise exposed community might react more adversely than predicted from the static exposure-response relationship on the basis of the worsening of their original environment. This argument has been used to justify lower noise acceptability criteria for noise sensitive developments in "green field" locations and has been opposed on the basis that any initial strongly adverse reaction is an initial response only that will eventually settle back to the expected level of response from the static exposure-response relationship.

3.7

In reality, over a period of time, most communities see changes in the degree of noise exposure. These dynamic exposure effects are not taken into account by field surveys as it would be impracticable to do so, particularly in the case of the tendency of some sections of the population to move house fairly often. It has been argued that residents immediately adjacent to major noise sources (eg airports or motorways) become self selected over a period of years as less sensitive than average as the more sensitive of the

population gradually move away. This sensitivity self-selection model explains initial strongly adverse reactions on the basis of a latent period during which the more sensitive of the population retreat from the exposure. There is little evidence to support this model particularly as convenient locations and other benefits often appear to outweigh the reduction in the proportion of the population who might be prepared to move into a noise exposed area in terms of the relative house prices in quiet and noisy areas.

3.8

There have been some studies of dynamic exposure situations, for example before and after various noise control measures. In these cases it is difficult to separate out the effects of the respondent's satisfaction at having had something done about his problem from the actual effects of the noise reduction achieved particularly in the light of possible perceptual constancy effects. Noise insulation of the building facade does not alter exposure outdoors and might often be applied only in response to some increase in outdoor noise exposure in any case. Full experimental control would require either blind studies or exposure condition balances that might be impossible to achieve in practice. Therefore the most useful purpose of such before and after studies might be to explore the degree of satisfaction with the work directly without addressing the question of whether the degree of acceptability of the noise exposure has changed.

3.9 Laboratory Simulations

The laboratory simulation approach provides a useful tool for the investigation of these dynamic situations by enabling the adoption of repeated measures experimental designs. A simulated domestic living room (or other appropriate indoor space) with concealed or otherwise unobtrusive loudspeakers can be used to reproduce realistic and representative indoor noise environments to representative samples of the population who would normally be assumed to be otherwise disinterested in the noise exposures except insofar as they are asked for their opinions. At present there are simulated living room listening laboratories at ISVR, the Transport and Road Research Laboratory and the National Physical Laboratory and at other institutions both in the UK and abroad. The laboratory simulation approach suffers from the major disadvantage of limited noise exposure condition duration. In addition, it is difficult to be certain of the extent to which experimental subjects in the laboratory will contrive their responses in order to comply with their perception of the experimenter's wishes rather than giving a true response. However, laboratory-field comparisons have shown good correlations in the sense of being able to derive experiments which are only feasible in the laboratory. Much of what we know today in respect of noise scales and indices derives not from field work but from laboratory studies, many of which were carried out in highly controlled acoustical environments such as anechoic chambers in order to avoid as much as possible the potentially confounding effects of field variables. The laboratory study can be thought of as providing a means for the development of scales of annoyance or dissatisfaction potential associated with noise environments, usually in a relative sense only as the powerful effect of the knowledge that an individual has to live with the noise environment he has at his personal dwelling place, does not apply.

4.0 DISCUSSION

4.1

Whereas noise-induced hearing loss associated with high industrial (or recreational) sound pressure levels is now relatively well understood and "safe" exposure criteria have been adopted, there is no consensus on the basis of research alone to determine acceptability criteria for community noise. Regulatory and administrative bodies and the courts are often forced to rely on the experience of expert witnesses for assistance in making decisions which might have profound implications either for the development of industry and transportation or for persons living in the vicinity of these developments. Many forms of noise control are expensive to implement or involve considerable inconvenience, for example night time moratoria or curfews. In many cases expert witnesses disagree, leading to serious problems for the non-expert adjudicators, and a test of reasonableness is often the only satisfactory approach.

4.2

The reason that experts can disagree is because the results of research are often open to different interpretations dependent upon point of view. For example there appears to be good evidence from field studies that aircraft noise is more annoying than road traffic noise at the same exposure levels but, as discussed above, this result depends on a number of assumptions as to the comparability of the data which might not be fully justified. Therefore, we are left with an established system of noise scales, indices and acceptability criteria which turn out upon detailed examination to be rather more arbitrary than at first sight might appear. This is unfortunate but the situation is not hopeless. First, even arbitrary criteria are better than none at all. Moves towards the adoption of a common noise index for all noise sources aid comparisons providing that the possibility of errors in specific circumstances is allowed for and can be rectified according to the results of research in the future. Second, complete and thorough investigation of the shortcomings of previous and current practice in the world of noise assessment might indicate promising future lines of resarch to build on the best of what has gone before.

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EXPOSURE TO PERCHLOROETHYLENE IN RESIDENTS LIVING ABOVE DRY-CLEANING ESTABLISHMENTS

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INTRODUCTION

Dry cleaning establishments in London are organised as receiving shops, coin-operated launderettes or dry-cleaners. Receiving shops are those which take in clothing for cleaning elsewhere. Launderettes have coin-operated machines for customers to dry clean their own clothes, and dry-cleaners are those where staff are employed to carry out dry-cleaning on the premises. Perchloroethylene (or tetrachloroethylene) is the solvent usually used in launderettes and dry-cleaners. Less frequently used are chemical agents such as 1,1,2-trichloro-1,2,2-trifluoroethane and trichloroethylene.

In inner city areas such as in London, land space is at a premium and housing accommodation located above commercial premises is common. Where people live above dry cleaning premises, concerns have been voiced about the smell from the shops below, and the extent of exposure to the chemical agents used for dry-cleaning. While many surveys of perchloroethylene exposure of staff employed in dry-cleaning establishments have been done,[1-4] there are few studies on such exposures in residents near dry-cleaning shops. We report on a survey done on these residents in a London borough.

AIMS

The aim of the survey was to assess the extent of perchloroethylene exposure and absorption among residents living above dry cleaning premises in the borough.

METHODS

Dry cleaning premises in the borough were identified by staff of the local environmental health department. A check-list was used to ascertain whether these were receiving shops, launderettes, or dry-cleaners.

Information was obtained on the main solvent used at these premises, and whether there were residents in accommodation above. All residents above premises using perchloroethylene as the main solvent were selected as potential study participants. Adult residents agreeing to participate were administered a questionnaire, and provided a 10 ml sample of venous blood taken during the day for determination of the presence of perchloroethylene. The laboratory detection limit for perchloroethylene in blood is 0.1 umol/l. Organic vapour air monitoring badges were used for environmental monitoring for perchloroethylene in the residences.

RESULTS

a) The study premises and participants

There were eighty-three dry-cleaning premises in the borough, of which 35 had residential accommodation above, and perchloroethylene was used as the main solvent by the shops below. 33 adult occupants (18 males and 15 females with an average age of 48 years) of 16 residences answered the questionnaire. The respondents have occupied their present accommodation for periods ranging from 1 month to 33 years. Twenty-eight participants provided blood samples.

b) Unusual odours in the homes

A third of the residents said they noticed unusual odours in their homes, but the description of the odours were varied, ranging from musty, damp, or acid smell to chemical smell. The odour threshold for perchloroethylene is 50 ppm [5]. This is higher than the levels of perchloroethylene that were measured in these homes. However, considerable variation exists between individuals in odour thresholds.

c) Environmental levels of perchloroethylene

Perchloroethylene was detected in all the film badges left in the premises. The amounts ranged from 0.1 to 36.1 ppm. The average level was 6.3 ppm. The occupational exposure limit for perchloroethylene is 100 ppm [6].

d) Blood levels of perchloroethylene

Blood analysis showed perchloroethylene to be present in 20 (71%) samples (Table 1). Levels ranged from 0.3 to 13.4 umol/l, with a mean value of 3.3 umol/l. The higher blood perchloroethylene levels tended to be in the residences with higher environmental perchloroethylene levels.

Seven of the blood samples were from individuals who also worked in dry-cleaning shops. There were 3 pressers, 2 part-time assistants and 2 managers. Two individuals have also visited a dry-cleaning shop within the two weeks prior to providing the blood sample. Even with the exclusion of these 9 individuals, there remain 11 residents with no occupational or recent casual exposure to perchloroethylene, who have perchloroethylene detected in the blood.

Nine of the 33 respondents (27%) to the questionnaire reported a group of symptoms consistent with effects of organic solvents. However, when compared to the remaining 24 respondents, there was no significant difference in their blood perchloroethylene levels.

In the UK there are no biological standards for perchloroethylene in the blood. Action levels of 1.5 umol/l to 6 umol/l have been suggested by some European countries for pre-shift blood samples from occupationally exposed workers. 1.5 umol/l is exceeded in blood samples from six residents with no occupational contact with perchloroethylene. They were from four different premises. 6umol/l is exceeded in samples from 3 individuals with no occupational exposure to perchloroethylene.

e) Inspection of premises

On inspection of the homes and the dry cleaning shops below, some factors were identified which could have contributed to the exposure of the residents to perchloroethylene. These factors were direct access to the accommodation through the dry-cleaning shops, age of the buildings, and unsatisfactory work practices in the shop. There was improper handling and storage of the solvent, and a lack of awareness of health and safety information and emergency procedures. Fewer of these factors were noted in the premises where residents had little or no absorption of perchloroethylene.

DISCUSSION AND CONCLUSIONS

All the premises studied showed perchloroethylene in air levels by passive monitoring to be below occupational exposure limits. However, some residents of these premises have blood perchloroethylene above action levels recommended for occupationally exposed individuals. Also, 29% of the blood samples showed no detectable perchloroethylene. Factors have been identified in the premises and the shops below which if reduced or eliminated can minimise the exposure and absorption of perchloroethylene by these residents. Adequate education and training of users of the chemical are of prime importance. Proper venting of perchloroethylene from the machines, and complete separation of housing accommodation and commercial premises using chemicals should be the ideal to aim for.

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TABLE 1. Perchloroethylene detected in blood samples

	No. of blood samples	Samples with perchloroethylene
Blood samples from residents employed in dry-cleaning	7	7 (100%)
Blood samples from residents not employed in dry-cleaning	21	13 (62%)
Total	28	20 (71%)

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CHEMICAL SENSITIVITY IN PATIENTS REFERRED TO THE DEPARTMENT OF ALLERGY AND ENVIRONMENTAL MEDICINE AT THE LISTER HOSPITAL

by
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SUMMARY

The incidence of chemical sensitivity among patients referred to the Department of Allergy and Environmental Medicine, Lister Hospital, London, was investigated through a retrospective survey of patient case notes covering 3 months.

Of the 171 new patients seen 38% had given affirmative responses to a questionnaire indicating symptoms provoked by chemicals. These patients were then tested for chemical sensitivity using the provocation/neutralisation method. 52% of patients also recorded sensitivities to foods. Patients' sensitivities to foods and particular biological allergens were assessed. Food sensitivity assessments were undertaken by elimination and challenge followed by the provocation/neutralisation technique to inhalant sensitivities by the latter and by the MAST technique.

Of the 171 new patients seen, 79 (46%) had been diagnosed as sensitive to pesticides. Blood levels of chlorinated pesticides were estimated in 30 (18%) and all tested showed levels of more than one compound. All patients were multiple sensitive and all bar one to food items as well. It was not possible to define a cluster of patients as chemically sensitive, nor infer any causative association between pesticides and the 'allergic syndromes' seen. It is however reasonable to infer that pesticides could contribute along with many other allergens to the 'allergic syndromes'.

The findings indicate that chemical hypersensitivity is common amongst patients who have food and inhalant sensitivities also. Chemical sensitivity can be defined as sensitivity to ambient levels of chemicals in food, air and water. Patients exhibiting this type of sensitivity are at risk as much from indoor pollutants as from outdoor pollutants.

The estimated incidence of allergic sydnromes, such as asthma, eczema, rhinitis, migraine and urticaria in the population is 15% with a further 15% showing indications of allergy but not needing continuous management of their symptoms. Other syndromes could also be included, eg colitis, rheumatoid arthritis, as there are indications in these conditions also. The findings strongly suggest the need for assessment of patients with allergic complaints or other complaints now being clustered with them, for chemical sensitivity.

The sources of the chemical contaminants are diverse, many are airborne pollutants. The contribution of ambient chemicals to the production of symptoms in the population must be considered and is likely to be a major factor.

1 The Department of Allergy and Environmental Medicine

1.1 This practice, initially established on a part time basis in 1980, has been a full time practice since 1982 and has moved recently from Nightingale Hospital to Lister Hospital in South West London. There are 4 Clinicians in the Department headed by Dr. J. Monro. The main practice including in-patient facilities is based at Lister with two other peripheral clinics in Hertfordshire.

1.2 There is no identifiable catchment for this specialist practice. Most patients are referred by consultants in London teaching hospitals especially from the Departments of Otolaryngology, respiratory medicine and immunology. Patients are also referred by practitioners around the country with some international referrals.

1.3 The practice is outside the National Health Service and the patients are seen on a fee for service basis, though

a large proportion of patients are covered by private insurance.

2 Departmental Protocol

The usual departmental protocol is as follows:

2.1 Clinical History

This is initially ascertained through a questionnaire (Appendix 1) completed by the patient prior to his/her initial consultation. The questionnaire amongst others includes the following four questions.

1. Do traffic fumes upset you?
2. Do crop sprays or pesticides affect you?
3. Do gas fumes upset you?
4. Do enclosed shopping areas upset you?

Detailed history on exposure and sensitivity to chemicals and pesticides is elicited at the time of the initial consultation.

2.2 Clinical Diagnosis and Management

2.2.1. Challenge

Patients are examined and then admitted for a 12 day programme. The programme is of 5 days abstinence from common foods followed sequentially by single food challenge. The foods challenged are generally organically grown and if no symptoms are engendered commercially grown foods are used for the challenge to establish reactions if any to contaminants which may include pesticides. The protocol used for challenge is attached (Appendix 2).

2.2.3 Provocation and Neutralisation Techniques

Testing using the provocation/neutralisation technique is undertaken thereafter and this involves testing for sensitivity to food, inhalants and chemicals. The range of chemicals tested and the protocol for testing is attached (Appendix 3).

2.3 Laboratory investigations

Other than routine biochemistry and haematology a series of special investigations are carried out by the Department. They include tests for trace elements, antibody screens, immunoglobulin assays and blood levels of chlorinated pesticides. The latter is done in Texas by Enviro Health Systems, Inc.* Also MAST assay is undertaken for inhalant antibody presence to 35 allergens.

2.4 Costs

Though the protocol described above is adopted in the Department as far as possible, in many instances in-patient treatment and laboratory tests are ruled out for financial reasons.

3 Methods/Design

3.1 All new cases were seen over a period of 3 months.

3.2 Information was retrieved from patient case notes onto specially designed coding sheets (Appendix 4). This covered personal particulars, clinical history, diagnosis, clinical tests and laboratory investigations.

3.3 The data was entered onto a micro-computer for analysis.

4 Findings

4.1 Patient characteristics

There were 171 new patients seen in the 3 months investigated of which 108 (63%) were women and 124 (73%) of working age (Table 1). The majority (54%) of patients seen were town dwellers.

4.2 Clinical diagnosis of chemical sensitivity was made in all patients.

4.3 Having an affirmative response to the questionnaire patients were further questioned on taking a history as to their reactions to other chemical exposures.

viz. chlorine - swimming pools, baths, ingested tapwater
perfume - scented toiletries

cigarette smoke
cleaning materials
newsprint
paint fumes
others encountered at work, eg
photocopying paper
industrial chemicals
marker pens.

100% of the patients who complained of chemical sensitivity to the 4 initial questions on the medical questionnaire also had one or more affirmative response to other chemicals in this group.

4.4 Patients were tested by the provocation/neutralisation technique (see 2.2.2). 100% of the patients who complained of reactions to chemicals had positive reactions to the chemicals on provocation/neutralisation.

4.5 Clinical diagnosis of pesticide sensitivity

A clinical diagnosis of pesticide sensitivity was made in 79 (46%) of patients (Table 2), a large proportion of them being women: 52 (66%). Of the children seen in the Department 13 (32%) were diagnosed to be sensitive to pesticides.

4.6 Challenge

Of the 79 patients diagnosed as sensitive to pesticide, 26 (33%) were challenged with organic and commercial food items. Positive tests, ie reaction to commercial food as opposed to organic food were seen in 17 (65%) patients so tested. (Table 3), 5 out of the 6 children challenged reacted positively and all have been prescribed organic food.

4.7 Pesticide levels

Of the 171 patients studied, 30 (18%) had chlorinated pesticide levels tested through Enviro Health Systems in the USA. All patients tested showed raised levels for one or more agents. Of the 30 tested (all with raised levels) 21 had been clinically diagnosed as sensitive (Table 4) and the rest as not sensitive to pesticides. Of the 26 patients challenged 10 (38%) had raised pesticide levels (Table 5).

Among patients with raised pesticide levels 4 were negative to challenge. 3 out of the 42 children were tested for pesticides and all of them showed raised blood levels.

4.8 Compounds

Of the 19 compounds tested, raised levels were seen for only 6. They were Dieldrin, Beta-BHC, DDT, DDE, Heptachlor Epoxide and HCB. These 6 compounds did feature in the top 7 of the US Reference. The frequency with which they appeared among the 30 patients were approximately of the same order as in the US Reference for DDT, DDE and HCB, but lower for Dieldrin and Beta-BHC and Heptachlor Epoxide (Table 6). Most patients had between 3-4 compounds in them with 1 having all 6 compounds in the blood (Table 7). The blood levels of these compounds in the patients tested are presented in Appendix 5.

4.9 MAST assays

107 of the patients had MAST assays undertaken for 35 allergens. The IgE antibody levels for these were assayed showing that (48%) of this group of patients had inhalant sensitivities. (Appendix 6).

4.10 Multiple sensitivity

Patients diagnosed as sensitive to pesticides were always sensitive to other agents (Table 8). All of them were sensitive to other chemicals and bar one to food items as well.

4.11 Clinical diagnosis

Most patients presented with classical atopic sensitivities to the Department, the chief presentation being eczema (15%) followed by allergic rhinitis (13%) and asthma (11%).

5 Limitations

Only 3 months data was analysed. A sample of 171 patients limits the power of inference, though it may be sufficient to show a trend.

6 Conclusion

The high percentage of patients (38%) indicating chemical sensitivity in the initial questionnaire and amplified on the taking of a clinical history, 100% of whom had corroboration of this by the provocation/neutralisation technique shows a large group of patients with common allergic complaints to be sensitive to chemicals. The chemicals in question are:

- hydrocarbons from traffic fumes
- pesticides
- gas fumes
- indoor pollutants in shopping centres (this group was deemed to include formaldehyde as the commonest component of dressings on new fabrics - clothing, carpeting and upholstery; perfume, cleaning agents).

All of these patients also showed sensitivity to other ambient chemicals. The definition of chemical sensitivity is sensitivity to ambient levels of chemicals in food, air and water. 100% of these patients with chemical sensitivity also exhibited food sensitivities.
MAST assays showed of a group of 107 of them that (63%) had sensitivities to inhalant allergens as well.

Multiple sensitivities are therefore common in patients with allergic syndromes including asthma, eczema, rhinitis, migraine. Though the patient coming to us may well be thought to be a special group these complaints are common in the population. Therefore our assessment could be extended to others with these complaints in the community and represent a different viewpoint for assessment. No mechanisms have been ascribed here but it is clear that once an individual is destabilised with regard to environmental provocants, be they food, biological inhalant particles or chemicals multiple sensitivity is common. The implication is that scrutiny of the quality of air, food and water for chemical contamination is vitally necessary.

ACKNOWLEDGEMENT

The data on pesticides quoted in this paper are being published elsewhere, in Clinical Ecology (in press).


Percentage reporting sensitive to Environmental factors
(June -August 1986)
Percent
60
50
40
30
20
10
0
Food
Traffic fumes
Pesticides
Gas fumes
Shopping area
Environmental factors

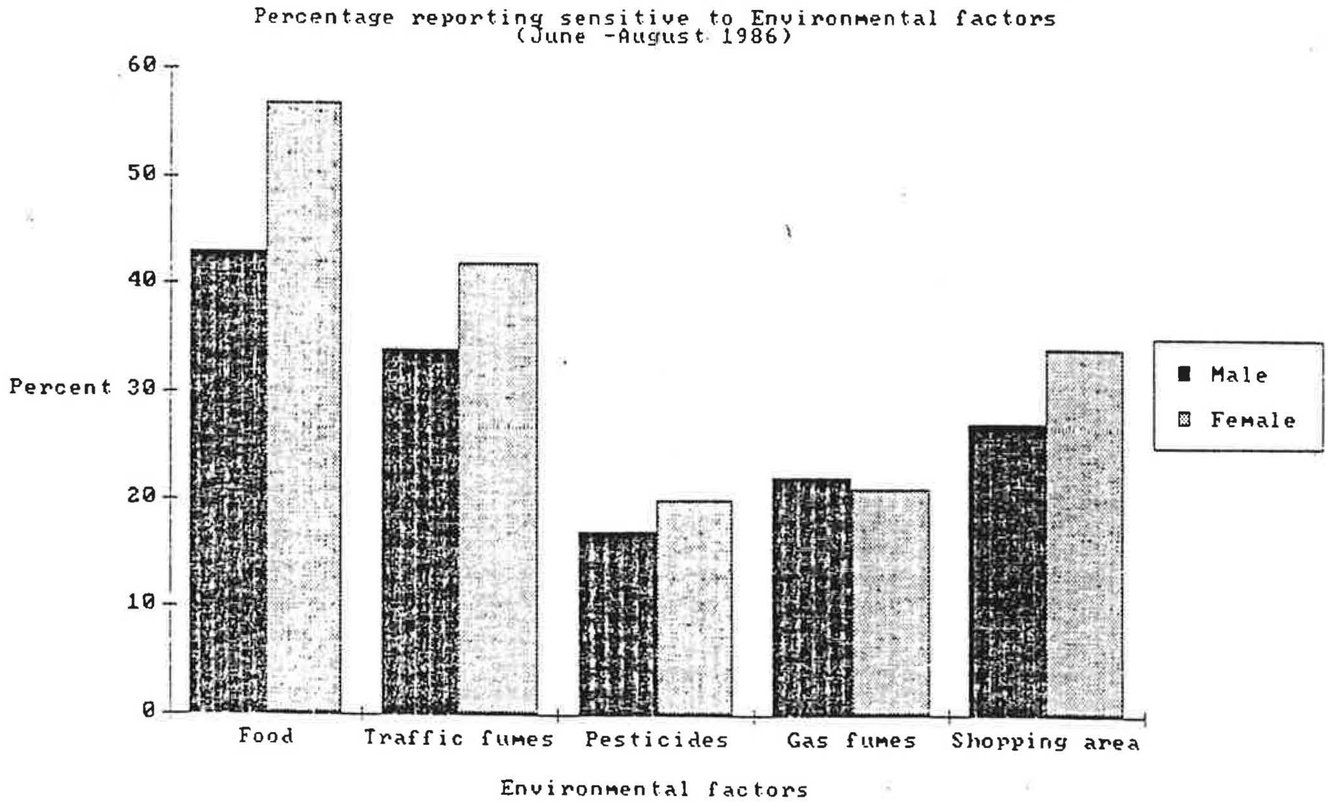
Percentage reporting sensitive to Environmental factors
(June -August 1986)
Percent
60
50
40
30
20
10
0
Food
Traffic fumes
Pesticides
Gas fumes
Shopping area
Environmental factors
Male
Female

TABLE 1

NEW PATIENTS SEEN IN THE DEPARTMENT

JUNE - AUGUST 1986

BY AGE AND SEX

	0-14	15-64	65+	ALL AGES
MALE	24	39	1	65*
FEMALE	17	85	4	106
TOTAL	41	124	5	171

* 1 Missing

TABLE 2

CLINICAL DIAGNOSIS OF PESTICIDE SENSITIVITY AMONG

NEW PATIENTS SEEN IN THE DEPARTMENT

JUNE - AUGUST 1986

BY SEX

	MALE	FEMALE	TOTAL
CLINICALLY DIAGNOSED AS SENSITIVE TO PESTICIDES	27	52	79
OTHERS	36	56	92
ALL PATIENTS	63	108	171

TABLE 3

RESPONSE TO FOOD CHALLENGE AMONG
NEW PATIENTS SEEN IN THE DEPARTMENT
JUNE - AUGUST 1986
BY AGE AND SEX

		0-14	15-44	65+	ALL AGES
POSITIVE REACTION TO BOTH COMMERCIAL AND ORGANIC FOOD (-VE TEST)	M	-	3	-	3
	F	1	5	-	6
POSITIVE REACTION TO COMMERCIAL FOOD BUT NOT TO ORGANIC FOOD (+VE TEST)	M	2	2	-	4
	F	3	10	-	13
ALL PATIENTS CHALLENGED	M	2	5	-	7
	F	4	15	-	19

TABLE 4

PESTICIDE LEVELS AND CLINICAL DIAGNOSIS OF PESTICIDE SENSITIVITY

AMONG NEW PATIENTS SEEN IN THE DEPARTMENT

JUNE - AUGUST 1986

		NUMBER WITH RAISED PESTICIDE LEVELS
CLINICALLY DIAGNOSED AS SENSITIVE TO PESTICIDES	79 (100%)	21 (27%)
OTHER	92 (100%)	9 (10%)
TOTAL	171 (100%)	30 (18%)

TABLE 5

PESTICIDE LEVELS AND RESPONSE TO FOOD CHALLENGE

AMONG NEW PATIENTS SEEN IN THE DEPARTMENT

JUNE - AUGUST 1986

		NUMBERS WITH RAISED PESTICIDE LEVELS
POSITIVE REACTION TO BOTH COMMERCIAL AND ORGANIC FOOD (-VE TEST)	9 (100%)	4 (44%)
POSITIVE REACTION TO COMMERCIAL BUT NOT TO ORGANIC FOOD (+VE TEST)	17 (100%)	6 (35%)
ALL PATIENTS CHALLENGED	26 (100%)	10 (38%)

Table 6

C.P.S.T. - CHLORINATED PESTICIDE SCREENING TEST
FREQUENCY PER 100 IN SAMPLE TESTED AMONG
NEW PATIENTS SEEN IN THE DEPARTMENT
(JUNE - AUGUST 1986)

Compound	U.S.A.	Lister Hospital
Aldrin	5.5	-
Dieldrin	65.5	26.6
Alfa-BHC	11.0	-
Beta-BHC	68.9	23.3
Gamma-BHC	2.3	-
Delta-BHC	0.2	-
DDT	48.4	43.3
DDE	98.1	100.0
DDD	1.9	-
Alpha-Chlordane	1.2	-
Gamma-Chlordane	1.3	-
Heptachlor	0.6	-
Heptachlor Epoxide	83.2	70.0
trans-Nonachlor	80.6	-
Endosulfan I	5.2	-
Endosulfan II	0.8	-
HCB	95.3	93.0
Endrin	2.5	-
Mirex	0.7	-

TABLE 7

PATIENTS WITH RAISED PESTICIDES LEVELS

BY NUMBER OF COMPOUNDS AND SEX

(JUNE - AUGUST 1986)

	1	2	3	4	5	6	Total
MALE	0	2	7	1	1	0	11
FEMALE	0	1	4	12	1	1	19
TOTAL	0	3	11	13	2	1	30

Table 8

MULTIPLE SENSITIVITY AMONG PATIENTS DEEMED CLINICALLY SENSITIVE TO PESTICIDES

	Food & Chemical	Chemical & Inhalants	Food, Chemicals & Inhalants	Food, Chemicals & Contact	Food, Chemicals Physical agents & Inhalants
MALE	3	0	18	2	5
FEMALE	1	1	30	2	17
TOTAL	4	1	48	4	22

TABLE 9

CLINICAL DIAGNOSIS AND PESTICIDE LEVELS

AMONG NEW PATIENTS SEEN IN THE DEPARTMENT

(JUNE - AUGUST 1986)

CLINICAL DIAGNOSIS	PATIENTS WITH RAISED PESTICIDE LEVELS	OTHERS
ECZEMA	3 (10%)	23 (16%)
ASTHMA	3 (10%)	15 (11%)
ALLERGIC RHINITIS	5 (17%)	18 (13%)
URTICARIA	3 (10%)	6 (4%)
'ATOPIC DISEASES'	14 (47%)	62 (44%)
MIGRAINE	3 (10%)	12 (9%)
IRRITABLE BOWEL SYNDROME	-	7 (4%)
POST-VIRAL SYNDROME	3 (10%)	8 (5%)
HYPERACTIVITY	-	6 (4%)
'OTHER'	10 (33%)	46 (33%)
ALL DIAGNOSES	30 (100%)	141 (100%

TABLE 10

CLINICAL DIAGNOSIS (PRESENTATION) AND CLINICAL ASSESMENT OF PESTICIDE SENSITIVITY AMONG NEW PATIENTS SEEN IN THE DEPARTMENT (JUNE - AUGUST 1986)

CLINICAL DIAGNOSIS	CLINICALLY DIAGNOSED AS SENSITIVE TO PESTICIDES	OTHERS
ECZEMA	9 (11%)	17 (18%)
ASTHMA	12 (15%)	6 (7%)
ALLERGIC RHINITIS	11 (14%)	12 (13%)
URTICARIA	2 (3%)	7 (8%)
'ATOPIC DISEASES'	34 (43%)	42 (47%)
MIGRAINE	8 (10%)	7 (8%)
IRRITABLE BOWEL SYNDROME	6 (8%)	1 (1%)
POST-VIRAL SYNDROME	5 (6%)	6 (7%)
HYPERACTIVITY	3 (4%)	3 (3%)
'OTHER'	23 (29%)	34 (37%)
ALL DIAGNOSES	79 (100%)	92 (100%)

Table 11 - Percentage reporting sensitivity to environmental factors

52% of patients reported sensitivity to food
39% of patients reported sensitivity to traffic fumes
20% of patients reported sensitivity to pesticides
22% of patients reported sensitivity to gas fumes
30% of patients reported sensitivity to shopping areas.

Broken down into % between male and female these showed a preponderance of females in all cases. (Table 12).

APPENDIX 1

Name .... Date ....
Address .... Tel. .... MAIN SYMPTOM
....

Occupation: Age: Height: Weight: D/P
Pulse (First thing before eating): Do you live in town or country: Near main road
Is there gas in the house: Coal fires: Do you smoke: Any smokers in the family: Where do you shop

MEDICAL QUESTIONNAIRE

(tick those which have occurred regularly over the past year)

1 ☐ Overweight
2 ☐ underweight
3 ☐ fluctuating weight
4 ☐ Skin: itching
5 ☐ burning
6 ☐ eczema
7 ☐ urticaria
8 ☐ itching scalp
9 ☐ dandruff
10 ☐ Abdominal Cramps
11 ☐ nausea
12 ☐ diarrhoea
13 ☐ constipation
14 ☐ bloating after meal
15 ☐ Flatulence
16 ☐ colitis
17 ☐ Weeping eyes
18 ☐ itching eyes
19 ☐ visual problems
20 ☐ Sneezing
21 ☐ sinusitis
22 ☐ itching nose
23 ☐ runny nose
24 ☐ post nasal drip
25 ☐ Sore throat
26 ☐ hoarseness
27 ☐ cough
28 ☐ catarrh
29 ☐ wheezing
30 ☐ bronchitis
31 ☐ Ears: ringing
32 ☐ aching

109 ☐ Mouth ulcers
33 ☐ Cold
34 ☐ hot
35 ☐ sweating
36 ☐ Pulse: fast
37 ☐ slow
38 ☐ breathlessness
39 ☐ Frequency micturition
40 ☐ water retention
41 ☐ Dark puffy circles under the eyes
42 ☐ Aching: muscles
43 ☐ joints
44 ☐ back
45 ☐ fibrositis
46 ☐ Fatigue for no reason
47 ☐ drowsiness
40 ☐ especially after meals
49 ☐ waking up tired
50 ☐ Clumsiness
51 ☐ floating feeling
52 ☐ tenseness
53 ☐ headaches (tension)
54 ☐ Nervousness
55 ☐ Insomnia
56 ☐ waking during night
57 ☐ hypoactive
58 ☐ hyperactive
59 ☐ hysterical
60 ☐ mental confusion
110 ☐ Tingling lips

111 ☐ Cramp
61 ☐ Inability to concentrate
62 ☐ forgetfulness
63 ☐ depression
64 ☐ anxiety state
65 ☐ irritability
66 ☐ aggressiveness
67 ☐ Cannot miss or be late for a meal
68 ☐ obsessional eating
69 ☐ eating for comfort
70 ☐ craving for a specific food
71 ☐ poor appetite
72 ☐ High blood pressure
73 ☐ Low blood pressure
74 ☐ Were you ever bottle fed

When are you worse:-
75 ☐ Spring
76 ☐ Summer
77 ☐ Autumn
78 ☐ Winter
79 ☐ At home
80 ☐ At work
81 ☐ On holiday
82 ☐ First thing in morning
83 ☐ Daytime
04 ☐ Night
85 ☐ Before meals

86 ☐ After meals
87 ☐ After shopping
89 ☐ In heavy traffic
89 ☐ All the time
00 ☐ Have you ever taken cortisone

LADIES ONLY
D1 ☐ Menopause
Menstrual cycle:-
92 ☐ Regular
93 ☐ Irregular
94 ☐ Amenorrhoea
95 ☐ Painful
96 ☐ Cysts: breast
97 ☐ ovarian
90 ☐ Toxaemia pregnancy

Contraceptive pill dates:-
Pregnancy dates:-
Miscarriage dates:-

ations:-

Diagnoses:- 99 ☐ Migraine. 100 ☐ Myxoedema.
101 ☐ Ulcerative Colitis. 102 ☐ Thyrotoxicosis
103 ☐ Multiple Sclerosis 104 ☐ Agoraphobia
105 ☐ Osteo – Arthritis 106 ☐ Schizophrenia
107 ☐ Rheumatoid Arthritis others:-
100 ☐ Asthma

History of Past Illnesses:- (other than normal childhood)

List of Known Allergies:- (including drugs)

ly History:-

drugs/medicine you taking now:-

Name of your Doctor ....
Address ....
....
.... Tel No ....

APPENDIX 1 (CONT)

Describe a typical days diet

Breakfast

Lunch

Tea

Dinner

How often, if at all, do you consume the following:

	never	in-frequently	sometimes	regularly or daily	more frequent
1. bread					
2. coffee					
3. tea					
4. alcoholic drinks					
5. chocolate					
6. sugar (cane) brown					
7. oranges					
8. corn and corn products					
9. pork/bacon					
10. preserved meats					
11. milk					
12. cheese					
13. cakes or biscuits					
14. eggs					
15. potatoes					
16. beetroot or beet sugar (white)					
17. tomatoes					
18. cereals/breakfast foods					
19. fish					
20. beef					
21. lamb			✓		
22. salt					
23. nuts					
24. soft drinks					
25. root vegetables					

Space left for any food not listed above.

6 What medicines do you take?

7 Is there any food that you eat at least one a day (or crave for)?

8 Since your symptoms started, have you increased your intake of any food?

9 Do you eat regularly, and how many times a day?

0 Is there any food you dislike?

1 Is there any food that you avoid because it disagrees with you?

2 How often, if at all, do you eat out?

3 When you were a child were there any foods you disliked, or felt ill after eating?

4 Do traffic fumes upset you?

5 Do crop sprays or pesticides affect you?

6 Do gas fumes upset you?

7 Do enclosed shopping areas affect you?

APPENDIX 2

PROTOCOL FOR CHALLENGES

FOOD CHALLENGES

1 An average portion of the food to be challenged is given to the patient.

2 The resting pulse and other existing symptoms are noted.

3 Constant monitoring of pulse and symptoms are made at 20, 40 and 60 minutes.

4 Other observations are monitored as appropriate, e.g. blood sugar, ECG, and peak flow readings.

APPENDIX 3

LIST OF CHEMICALS TESTED:

Phenol
Ethanol
Formalin
Glycerol
Diesel fumes
Terpenes
Perfume

Protocol for Provocation-Neutralisation Method

This is a method which consists of the production of symptoms by giving an intradermal injection of a provoking dose of a food extract, these symptoms are then relieved by giving successive intracutaneous injections of other dilutions of the same extract until the neutralising dose is found.

Serial dilutions of antigens starting with a stock extract which is diluted in a 1:5 ratio in a diluent are prepared. Patients are injected intradermally with a dose of antigen - usually 0.01 ml of a 1:5 strength to begin with. The size and characteristics of the resultant wheal are recorded initially and after 10 minutes. During the 10 minute interval, many common symptoms can be induced. A further intradermal injection of 0.01 ml of a 1:2500 strength can be given. Symptoms may again be induced. The neutralising dilution is generally that dose which gives the first negative wheal which does not grow more than 2 mm in each direction. Wheals which are blanched, hard, raised or discoid are positive and those which are soft, pink and flat or irregular are negative. The neutralising wheal coincides with the negation of symptoms at the end of the ten minute period.

APPENDIX 4

GENERAL CHARACTERISTICS

AGE

SEX
(1 Male 2 Female)

HEIGHT
(in Inches)

WEIGHT
(in lbs)

OCCUPATION

AREA
(1 Town 2 Country)

GAS
(1 Yes 0 No)

COAL
(1 Yes 0 No)

SMOKING
(1 Yes 0 No)

Is there any food that you avoid because it disagrees with you?
(1 Yes 0 No)

Do traffic fumes upset you?
(1 Yes 0 No)

Do crop sprays or pesticides affect you?
(1 Yes 0 No)

Do gas fumes upset you?
(1 Yes 0 No)

Do enclosed shopping areas affect you?
(1 Yes 0 No)

APPENDIX 4 (CONT)

SENSITIVITY

I FOOD	CLINICAL SENSITIVITY	TEST	SYMPTOM
GRAINS	☐	☐	☐
DAIRY	☐	☐	☐
YEAST	☐	☐	☐
ADDITIVES	☐	☐	☐
OTHER	☐	☐	☐

II CHEMICALS	CLINICAL SESITIVITY	TEST	SYMPTOM
FORMALIN	☐	☐	☐
TURPINE	☐	☐	☐
GLYCEROL	☐	☐	☐
ETHANOL	☐	☐	☐
PHENOL	☐	☐	☐
CHLORINE	☐	☐	☐
TOBACCO	☐	☐	☐
PERFUME	☐	☐	☐
DIESEL	☐	☐	☐
GAS	☐	☐	☐

	CLINICAL SENSITIVITY	CHALLENGE1	CHALLENGE2
PESTICIDES	☐	☐	☐

II INHALANTS	CLINICAL SENSITIVITY	TEST	SYMPTOMS
POLLENS	☐	☐	☐
DUST MITE	☐	☐	☐
MOULDS	☐	☐	☐
OTHER	☐	☐	☐

V PHYSICAL	CLINICAL SENSITIVITY		
SUNLIGHT	☐	☐	☐
COLD	☐	☐	☐
HEAT	☐	☐	☐
ELECTRO	☐	☐	☐
CONTACT	☐	☐	☐

APPENDIX 5 (1)

EPORT REQUIRES 976 BYTES FOR THIS TASK

Patients with positive Dieldrin levels cross-classified against other pesticides and their blood levels

ieldrin	Beta-BHC	DDT	DDE	Heptachl Epoxide	HCB
.20	0.00	0.00	.80	.40	.20
.20	.50	.40	9.50	0.00	1.60
.30	.10	.30	3.10	1.10	8.30
.30	0.00	0.00	1.80	0.00	.70
.30	0.00	.10	8.60	.80	2.40
.30	0.00	0.00	1.70	1.00	.50
.40	.50	0.00	10.40	0.00	2.60
.40	.60	0.00	7.10	0.00	1.60

his procedure was completed at 11:41:17

APPENDIX 5 (ii)

PORT REQUIRES 976 BYTES FOR THIS TASK

Patients with positive Beta-HCB levels cross-classified against other pesticides and their blood levels

a-BHC	Dieldrin	DDT	DDE	Heptachl Epoxide	HCB
.10	.30	.30	3.10	1.10	8.30
.10	0.00	0.00	.20	.50	.40
.10	0.00	.10	2.20	0.00	.40
.50	.40	0.00	10.40	0.00	2.60
.50	.20	.40	9.50	0.00	1.60
.50	0.00	0.00	3.00	.40	.60
.60	.40	0.00	7.10	0.00	1.60

je 27 SPSS/PC+ 11/28/86

.s procedure was completed at 12:04:20

APPENDIX 5 (iii)

PORT REQUIRES 976 BYTES FOR THIS TASK

Patients with positive DDT levels cross-classified against other pesticides and their blood levels

DDT	Dieldrin	Beta-BHC	DDE	Heptachl Epoxide	HCB
.10	0.00	.10	2.20	0.00	.40
.10	.30	0.00	8.60	.80	2.40
.10	0.00	0.00	3.80	.50	.40
.10	0.00	0.00	4.50	.50	.80
.20	0.00	0.00	1.80	.70	.30
.30	.30	.10	3.10	1.10	8.30
.30	0.00	0.00	2.00	0.00	1.00
.40	.20	.50	9.50	0.00	1.60
.40	0.00	0.00	14.10	.70	2.10
.40	0.00	0.00	4.80	.50	8.30
.40	0.00	0.00	13.00	1.30	1.10
3.90	0.00	0.00	8.10	.10	0.00
4.90	0.00	0.00	25.00	0.00	.50

ge 15 SPSS/PC+ 11/28/8

is procedure was completed at 11:51:22

APPENDIX 5 (iv)

:PORT REQUIRES 976 BYTES FOR THIS TASK

Patients with positive DDE levels cross-classified against other pesticides and their blood levels

DDE	Dieldrin	Beta-BHC	DDT	Heptachl Epoxide	HCB
.20	0.00	.10	0.00	.50	.40
.80	0.00	0.00	0.00	0.00	.30
.80	.20	0.00	0.00	.40	.20
.90	0.00	0.00	0.00	.50	.20
.90	0.00	0.00	0.00	.60	.20
.90	0.00	0.00	0.00	.70	0.00
1.70	.30	0.00	0.00	1.00	.50
1.80	0.00	0.00	.20	.70	.30
1.80	.30	0.00	0.00	0.00	.70
2.00	0.00	0.00	.30	0.00	1.00
2.10	0.00	0.00	0.00	2.60	.40
2.20	0.00	.10	.10	0.00	.40
2.30	0.00	0.00	0.00	.80	.60
3.00	0.00	.50	0.00	.40	.60
3.00	0.00	0.00	0.00	2.50	1.10
3.10	.30	.10	.30	1.10	8.30
3.50	0.00	0.00	0.00	0.00	.70

Patients with positive DDE levels cross-classified against other pesticides and their blood levels

DDE	Dieldrin	Beta-BHC	DDT	Heptachl Epoxide	HCB
3.80	0.00	0.00	.10	.50	.40
4.50	0.00	0.00	.10	.50	.80
4.80	0.00	0.00	0.00	1.60	.20
4.80	0.00	0.00	.40	.50	8.30
7.10	.40	.60	0.00	0.00	1.60
8.10	0.00	0.00	3.90	.10	0.00
8.60	.30	0.00	.10	.80	2.40
8.90	0.00	0.00	0.00	.90	.80
9.50	.20	.50	.40	0.00	1.60
10.40	.40	.50	0.00	0.00	2.60
13.00	0.00	0.00	.40	1.30	1.10
14.10	0.00	0.00	.40	.70	2.10
25.00	0.00	0.00	4.90	0.00	.50

je 18 SPSS/PC+ 11/28/8(

.s procedure was completed at 11:53:49

APPENDIX 5 (v)

EPORT REQUIRES 976 BYTES FOR THIS TASK

Patients with positive Heptachlor Epoxide levels cross-classified against other pesticides and their blood levels

eptachl poxide	Dieldrin	Beta-BHC	DDT	DDE	HCB
.10	0.00	0.00	3.90	8.10	0.00
.40	.20	0.00	0.00	.80	.20
.40	0.00	.50	0.00	3.0C	.60
.50	0.00	0.00	0.00	.9C	.20
.50	0.00	.10	0.00	.20	.40
.50	0.00	0.00	.10	3.80	.40
.50	0.00	0.00	.40	4.80	8.30
.50	0.00	0.00	.10	4.50	.80
.60	0.00	0.00	0.00	.90	.20
.70	0.00	0.00	.20	1.80	.30
.70	0.00	0.00	.40	14.10	2.10
.70	0.00	0.00	0.00	.90	0.00
.80	0.00	0.00	0.00	2.30	.60
.80	.30	0.00	.10	8.60	2.40
.90	0.00	0.00	0.00	8.90	.80
1.00	.30	0.00	0.00	1.70	.50
1.10	.30	.10	.30	3.10	8.30

Patients with positive Heptachlor Epoxide levels cross-classified against other pesticides and their blood levels

ptachl oxide	Dieldrin	Beta-BHC	DDT	DDE	HCB
1.30	0.00	0.00	.40	13.00	1.10
1.60	0.00	0.00	0.00	4.80	.20
2.50	0.00	0.00	0.00	3.00	1.10
2.60	0.00	0.00	0.00	2.10	.40

je 21 SPSS/PC+ 11/28/86

is procedure was completed at 11:56:43

APPENDIX 5 (vi)

'ORT REQUIRES 976 BYTES FOR THIS TASK

Patients with positive HCB levels cross-classified against other pesticides and their blood levels

ICB	Dieldrin	Beta-BHC	DDT	DDE	Heptachl Epoxide
.20	0.00	0.00	0.00	.90	.50
.20	.20	0.00	0.00	.80	.40
.20	0.00	0.00	0.00	4.80	1.60
.20	0.00	0.00	0.00	.90	.60
.30	0.00	0.00	0.00	.80	0.00
.30	0.00	0.00	.20	1.80	.70
.40	0.00	.10	0.00	.20	.50
.40	0.00	.10	.10	2.20	0.00
.40	0.00	0.00	.10	3.80	.50
.40	0.00	0.00	0.00	2.10	2.60
.50	0.00	0.00	4.90	25.00	0.00
.50	.30	0.00	0.00	1.70	1.00
.60	0.00	.50	0.00	3.00	.40
.60	0.00	0.00	0.00	2.30	.80
.70	.30	0.00	0.00	1.80	0.00
.70	0.00	0.00	0.00	3.50	0.00
.80	0.00	0.00	0.00	8.90	.90

Patients with positive HCB levels cross-classified against other pesticides and their blood levels

CB	Dieldrin	Beta-BHC	DDT	DDE	Heptachl Epoxide
.80	0.00	0.00	.10	4.50	.50
1.00	0.00	0.00	.30	2.00	0.00
1.10	0.00	0.00	0.00	3.00	2.50
1.10	0.00	0.00	.40	13.00	1.30
1.60	.20	.50	.40	9.50	0.00
1.60	.40	.60	0.00	7.10	0.00
2.10	0.00	0.00	.40	14.10	.70
2.40	.30	0.00	.10	8.60	.80
2.60	.40	.50	0.00	10.40	0.00
8.30	.30	.10	.30	3.10	1.10
8.30	0.00	0.00	.40	4.80	.50

ɜ 24 SPSS/PC+ 11/28/86

ɜ procedure was completed at 12:00:25

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1987 WORKSHOP
25-26 MARCH
MANCHESTER

INDOOR AIR QUALITY
ACCEPTABLE STANDARDS AND BUILDING DESIGN

CONTROLLING AIR QUALITY IN CAR PARKS

by

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CONTROLLING AIR QUALITY IN CAR PARKS

by
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School of Chemistry, Leicester Polytechnic

ABSTRACT

Pollution incidents in car parks occur in an acute but discontinuous manner. The factors which come together to cause such pollution incidents are analysed and a rough index described for analysing whether a car park will have such incidents or not.

Under certain circumstances, pollution incidents can occur in multi-storey car parks. The principal contributing factors are first, severe traffic congestion both within and without the car park, such that the rate of vehicles leaving the car park is very low. The actual rate is far less than the rate necessary for the number of people who wish to leave at that time. Second, when very stable weather conditions are allied to poor natural ventilation, the actual rate of ventilation of the car park can be very low. This situation can arise when a car park which has good ventilation is closely surrounded by further development which drastically reduces through draught. Third, congested, polluted conditions can arise in a car park due to a very slow rate of processing the charges. A large surge of vehicles may wish to leave at one time but only one kiosk is open. The situation worsens when there is no intervention by management.

Typical acute incidents involve 30-80 minutes exposure to carbon monoxide of up to 400-450 ppm for families ranging from the elderly to the very young. Car park attendants are also exposed to high carbon monoxide levels in some kiosks, in addition to high airborne levels of lead.

Survey results are presented and discussed in the context of

the design and construction of car parks. Proposals are made to reduce the incidence of air pollution in car parks and other enclosed spaces such as car ferries and customs posts.

A method for calculating an index of the pre-disposition of a given car park for sudden, acute, air pollution incidents is described which takes into account the flow capacity at peak times into the surrounding roads, the natural draught ventilation rate and the capacity of the management to respond to sudden peak flow rates of vehicles leaving the car park.

INTRODUCTION

There are many multi-storey car parks in redeveloped city centres, built as part of a plan to control road-side parking and aid traffic flow. These car parks are erected on sites which are either peripheral to a city centre or have built into, over or under shopping precinct developments. Such buildings are a common feature of developed countries; the literature shows a steady level of reports discussing air pollution arising from them. In addition, there are reports of air pollution arising from the use of internal combustion engines to power various unusual machines such as ice-polishers and miniature road sweepers within enclosed premises. Further, there are reports of high levels of vehicle fumes on car ferries and at relatively enclosed customs posts.

All of these reports describe high levels of carbon monoxide associated with very unpleasant exhaust fumes. A particular feature of air pollution incidents in car parks, whether they occur in the UK or other countries, is the sudden and acute nature of the incident. This work, conducted with Ivor Barker over a long period and encompassing a large number of car parks of different design and location, presents some of our results, analyses how these arise and what can be done to control and reduce these air pollution incidents.

RELEVANT LEGISLATION

The legislation on car parks is primarily concerned with their

design and construction, particularly with respect to fire precautions. They are covered by Section E2 (Structural Fire Precautions) of the Building Regulations, purpose group VIII (storage and general). Circular 17/68 of the then Ministry of Housing and Local Government also applies and further develops the fire precautions. The overall thrust is to safeguard car park construction and protect them from fire hazards. The problem of pollution from vehicles in the confined spaces of car parks does not appear in these regulations. The Institution of Structural Engineers has drawn the attention of its members to the need for considering vehicular pollution when designing multi-storey car parks.

AIR POLLUTION MONITORING

Carbon monoxide, as an indicator of air pollution in car parks can be measured reasonably accurately, to within 5%, using simple Draegar tubes, provided that a standard procedure is adhered to. The carbon monoxide tube is found to be particularly accurate when measured against standard gas mixtures. Lead in the air is determined by collection on a filter and analysed using atomic absorption techniques.

THE DIFFERENT TYPES OF CAR PARKS

The car park whose problems initiated this work was the most interesting of those investigated. It was designed and built to the relevant regulations and measures roughly 130 m x 130 m, with a clearance headroom of just over 2 m. It is situated on top of a shopping centre which occupies almost all of a central city block. The car park has two floors, the upper one being completely open. The lower floor has an extremely reticulated and obstructed configuration because of skylights, plant rooms, offices, service shafts and walls which protrude through from the development below. The lower is therefore a very thin sandwich, 130 m x 130 m maximum, with approximately 2 m headroom.

The draught movement for the lower floor was found to be at best only one-third of that measured for an identical position directly above it on the upper floor. However, the upper floor is the last to fill up and vehicles must return to the lower floor via a conflicting junction with lower floor traffic to leave the car park.

Detailed surveys for busy and quiet days identified two areas of high pollution levels. For the first area, at the internal traffic junction, on a busy day, continuous levels of carbon monoxide in the region of 40-60 ppm were recorded. These did not occur on quiet days. The second area of high pollution was the exit ramp of the car park. As the car park is on the top of a shopping development, vehicles use a helical ramp to climb up to it. This ramp is intertwined with a separate exist ramp, both being enclosed within a glazed reinforced concrete drum. Exit from the car park was substantially hindered, and frequently stopped, by traffic congestion in the city centre street which it entered. When this happens, the enclosed exit ramp becomes a small enclosed space with stationary vehicles running their engines, generally with their chokes out. Background values of 130-210 ppm carbon monoxide for periods of over an hour, with peak values of 450 ppm. These levels of carbon monoxide are inhaled by people sitting in vehicles relatively immobilised for periods of up to 30-40 minutes. In extreme cases, even longer periods of exposure can occur. The longest time known to us for congestion-caused delay in leaving a car park is 105 minutes (but not from this car park) in a major city centre just prior to Christmas.

The second car park is constructed of a ground floor and four upper floors, mainly open at the edges, overall dimensions 70 x 38 m with an average height of 3.1 m. In comparison with the first car park described, this one has a relatively open deck structure. The exit from this car park is on to a quiet street, with no congestion, leading to a ring road.

The polluted area in this car park was the tunnel-like exit where the factor determining the rate of exit was the payment kiosk. This car park is used continuously, being close to the city centre and with a rate structure which encourages shorter stays. On busy days, a continuous stream of traffic entered and left. For long periods of time there was an unbroken queue of cars waiting to leave and, for shorter periods of time, vehicles waiting to enter, both within the tunnel-like entrance. Hourly averages of carbon

monoxide of between 130 and 50 ppm were found between 1000 and 1900 on busy days. Concurrent hourly atmospheric lead measurements showed levels ranging between 17 and 4 $\mu g m^{-3}$ during this period.

Other car parks of this type surveyed showed good natural ventilation, less intensive use and very good road arrangements so as to move vehicles away. Their construction tended to taller, open deck structures, sometimes built over commercial developments such as car sales showrooms.

A different type of car park construction is the continuous ramp, either single or two ramps intertwined with separate entrances. These structures are usually massive, tall, buildings which stand alone and have good natural ventilation. The only areas of vehicle pollution found for this type of car park were the payment kiosk areas, again in a tunnel-like configuration at, or close to, ground level. Levels of carbon monoxide between 50 and 120 ppm were found in these areas on busy days as vehicles queued to leave the car parks. However, in each case, the exit from the car park was unhindered and traffic was able to disperse freely.

The final type of car park surveyed were those which are underground. The most interesting example of this type of car park used its site in a very complex manner. It was part of a comprehensive development of a railway station in a deep ravine. The lowest levels of the ravine were given over to a car park, approximately 400 x 80 m, the middle levels (at ground level) to a shopping centre development and, superimposed upon that, housing in upper levels.

At one end of the development, the car park on the lowest floor is the basement of a medium-size multi-storey car park sunk into the ground. As vehicles wend their way up through this car park, they eventually find their way up to ground level.

These two connected parts of the car park showed very different air pollution characteristics. The lowest level car park was positively ventilated through ducting. At peak times, the flow of vehicles within the car park was very positively organised by the management so as to maximise traffic flow. (It is my observation that traffic left to its own devices in confined areas tend to minimise traffic flow). Further, whereas there were normally two pay kiosks, at peak traffic flow times a third payment point was established by setting up a portable table and a cash till. The lower car park exited on to a quiet street, away from the main city centre traffic, with no hindrance to the rapid dispersal of vehicles.

Vehicles leave the other, sunken, multi-storey, part of the car park at ground level by circulating through the various levels. The pay kiosks are at the end of a steeply inclined ramp. Final exit from the car park is to a main city centre street. Due to the complex configuration of the car park, ventilation is poor. At peak times, a queue of vehicles fills the roadways of this car park all of the way down to the lowest level. Steady carbon monoxide levels of 400-450 ppm were recorded in this car park, with exit times of 25-30 minutes. 100-170 ppm carbon monoxide was observed over several hours on the exit ramp with values of 200-270 ppm for the same period at the pay kiosks. The management of this end of the car park was conspicuous by its absence.

DISCUSSION

The three factors which come together to cause acute air pollution incidents in car parks are:

-> inadequate natural or forced ventilation,

-> hindered vehicle dispersal from the car park,

-> poor management response to the sudden occurrence of air pollution incidents.

The levels of carbon monoxide found in some of these car parks are well in excess of OEL limits, not that OEL considerations apply to these situations. We are dealing exposure to the general public and much lower exposure limits must apply.

It should be emphasised that most car parks do not have air pollution incidents. Concern should only be directed towards those which are perceived to have recurring problems,

particularly at peak times such as pre-holiday shopping times, post-Christmas sales and also after theatre performances.

Measures can be taken to relieve the problem of acute air pollution incidents in car parks. The first car park described had the position of the exit moved slightly relative to a pedestrian crossing. This small change enabled the vehicles to enter the main street traffic stream more readily. The glazing on the helical ramps leading to and from the car park was first removed (showing up some very rough concrete) and then replaced such that the ventilation was not hindered. Illuminated notices, activated by carbon monoxide sensors, were installed when the levels rose. The notices told motorists to turn their engines off, but were generally ignored and are now defunct. The management now responds to anticipated congestion by having both kiosks open when necessary. The early problems of air pollution from motor vehicles in car parks have been considerably reduced.

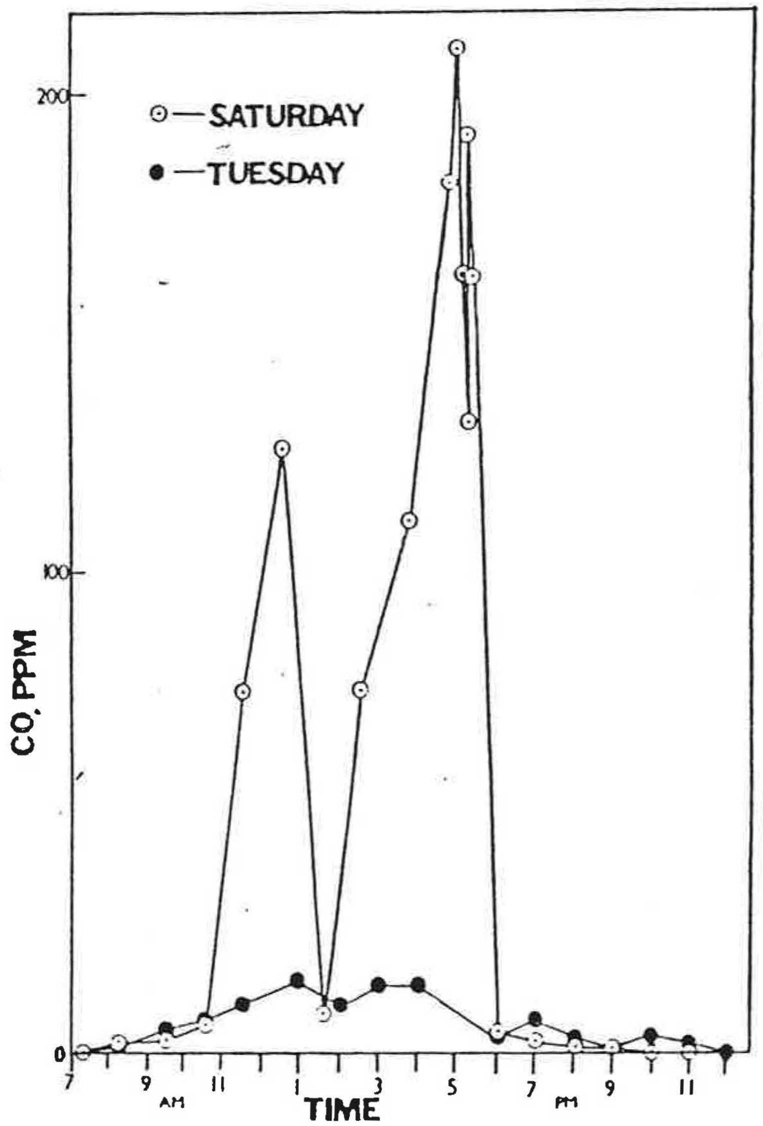
When development takes place close to car parks, the impact of the new building on the natural ventilation of those car parks should be considered. Changes in traffic flow caused by new building or revised road schemes should take into account any new hindrances to the ease of vehicles leaving the car park.

Management of car parks has to be aware of the problems that can arise and be prepared to respond to them. The exposure of car park employees to carbon monoxide over prolonged periods and also to lead particulates in the air can best be managed by ensuring a supply of clean air drawn from the outside of the car park to their kiosks. Car park employees often work very long shifts, so long as to render valueless the occupational exposure criteria of 8hrs/day, 5 days/week, etc.

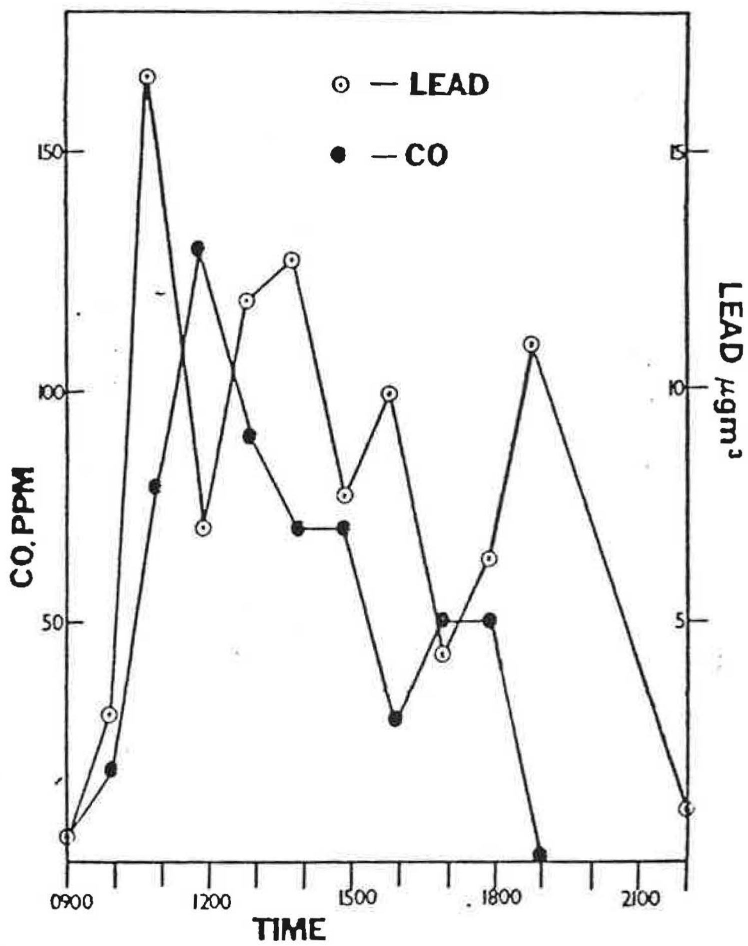
The diversity of car parks is such that when problems are encountered then an analysis of the form set out above should be undertaken. With careful thought, minor modifications can relieve or considerably reduce the problems of vehicular pollution in car parks.

REFERENCE

I.W. Barker and M.F. Fox, Royal Society of Health Journal, p.168, 1976.



1. Variation of carbon monoxide with time on the exit ramp of a car park for a Saturday and a Tuesday.



2. Hourly variations of lead and carbon monoxide within a kiosk of a car park.

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1987 WORKSHOP
25–26 MARCH
MANCHESTER

INDOOR AIR QUALITY
ACCEPTABLE STANDARDS AND BUILDING DESIGN

AIR FILTRATION TECHNIQUES

by
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AIR INFILTRATION TECHNIQUES

by
P.C. MacDonald

INTRODUCTION

One cannot really review air filtration techniques without first examining what it is that filters are designed to remove.

Atmospheric contamination is only too obvious during a hazy day in an industrial area or in the middle of a city. But even in apparently clean environments such as in the middle of a desert or out in the North Sea, there still is particulate matter suspended in the air.

This contamination, unless removed effectively by air filtration, can cause problems such as clogged heat exchangers within air conditioning units and stains around outlet grilles. Worse still, sub-standard filtration can lead to wound infection in hospitals and rejected components within the microelectronics industry, to name but two examples.

NATURE OF PARTICULATES WITHIN THE ATMOSPHERE

The three main, basic types of particulate matter to be found in the atmosphere are:

mineral
organic
carbonaceous.

Mineral matter is introduced into the air by the erosive action of wind on the soil and sand - hence the reason why desert air is not completely clean. Mineral matter also appears in the form of flyash from solid fuel boilers, and is discharged from cement works and many industrial processes.

Organic material can range from fibres to pollen, as sufferers from hay fever know only too well.

Carbonaceous material is disseminated into the atmosphere in vast quantities by the incomplete combustion of coal and oil, by car exhausts, and within the internal environment, by cigarette smoking.

The physical sizes of the particles in the atmosphere are so small it needs an optical or even electron microscope to make them individually visible. They are so minute the unit of measurement used in air filtration is a millionth of a meter, or micron as it is commonly known. A grain of pollen typically is 10 microns in diameter, a flyash particle is 5 microns, and tobacco smoke particles are only 0.3 microns. By comparison, a human hair is 60 microns in diameter.

However, although the particles might be microscopic, they are present within the atmosphere in vast numbers. In a city environment there can be well over 300 million particles contained within a cubic meter of air.

Typically, 92% of the particles are less than 0.5 micron in size. However, the mass of each of these is so negligible that they only constitute 1% of the total weight of the atmospheric particulate. Conversely, particles in the size range 10 - 80 microns, which account for only 0.005% by number of the total, comprise 28% by weight.

BASIC AIR FILTRATION TECHNIQUES

To meet the challenge of removing atmospheric contamination many different types of filter have been evolved. Each type has its applications and limitations, its advantages and disadvantages.

Whilst there may be numerous filter types, there are only three basic techniques of air filtration:

impingement
interception/diffusion
electrostatic precipitation.

It should be noted that filters handling atmospheric air do not normally utilise a sieving action. Whilst this mechanism is successfully employed in collecting dust from industrial processes, and in the separation of solids from liquids, it is not suitable for dealing with airborne contamination.

IMPINGEMENT TECHNIQUE

The impingement technique relies upon the inertia of particles within a moving airstream. As the air changes direction to flow around a target such as a fibre, the particles due to their inertia tend to continue in the original direction. The particles therefore collide with the target and are captured.

The fibres are normally bonded together in the form of a mat up to 50 mm thick through which the air flows at a velocity between 1.5 and 3 m/s. Below this velocity range particles have insufficient inertia and so can avoid collision. Above 3 m/s there is an increasing likelihood of particles bouncing off the fibres instead of being retained.

Glass is the most popular fibre material, spun in the form of continuous filaments which are bonded together to form a matrix. For the best results the glass fibres are coated with a viscous oil or gel which helps ensure that particles are retained. The gel also provides a wicking action, coating captured particles so that they in turn also act as targets for capturing other particles.

Another device for improving effectiveness is graduated density medium. This is manufactured with larger diameter fibres in a more open weave at the air entry side of the material, designed to capture the larger particles. Through the depth of the medium the fibre diameter is progressively reduced and they are woven closer together, so the smaller particles are caught towards the air leaving face. This way the filter medium does not face load, but captures particles throughout its entire depth, thereby providing a much improved dust holding capacity.

The dust holding capacity is a vital but often overlooked facet of filter performance. Two filters of equal efficiency can have a fivefold difference in dust holding capacity. Since the latter determines the useful life of a filter it is of prime economic importance. The cheapest filter on a first cost basis may well be a bad buy when looked at properly on a life cycle basis.

IMPINGEMENT FILTERS

The glass fibre medium is made up into the form of throw-away panel filters, which are changed when their pressure drop due to dirt build-up reaches the manufacturer's recommended level. This is typically 125 Pa. Throw-away panels are the most popular of all filters due to their low cost and millions are used every year either on their own, or as pre-filters to protect more efficient secondary filters.

Panel filters can also be made from a washable material such as plastic foam or expanded metal foil. However, due to the high cost of maintenance these are not really an economic alternative to the throw-away filter.

Filter medium can be made up into a roll which is fed across the duct by an automatic roll filter. This provides the advantages of virtually constant pressure drop and long intervals between filter changes. But in recent years the roll filter has fallen completely from popularity due to maintenance problems and relatively high costs.

Impingement filters do not all utilise fibrous media. Automatic self-cleaning filters are available which present a labyrinth of louvred metal panels designed to force the air stream to make a series of abrupt changes of direction. The dirt particles impinge onto the panels, which are oil wetted for retention purposes. The plates are automatically bathed in oil to clean off the dirt and to provide a fresh coating of oil. Since the filter is automatic, and does not use expensive filtration media, this type is ideal for the Middle East where there are sand storms.

Filters which utilise the impingement principle are able to remove anything up to 95% by weight of the particulate matter in the air. However, they are not effective against the smaller particles, those under 1 micron in size, which comprise the greatest number of particles.

INTERCEPTION/DIFFUSION

The sub-micron particles cause staining of ceilings, walls and furnishings. A thimblefull of carbon black is sufficient to discolour an area the size of a tennis court. It can be shown analytically that the most difficult particles of all to capture are those of around 0.3 micron size. For these, and the other sub-micron sized particles, a different filtration mechanism is utilised - that of interception/diffusion.

Interception occurs when the air moves slowly through the filter medium, slow enough to avoid aerodynamic interference between the fibres and the approaching particles. The particles, in this situation, do not move round the fibres, but instead make contact and are captured.

The process can be considerably aided by diffusion. The gas molecules of air are in a state of constant movement. Particles smaller than 0.5 micron are of such negligible mass that they are affected by the colliding gas molecules, and move in a random fashion, known as 'Brownian Motion'. This random motion increases the possibility of the particle striking a fibre surface and hence being removed.

INTERCEPTION/DIFFUSION FILTERS

Bag filters, which employ the interception/diffusion technique, utilise a high ratio of filter medium to face area to achieve a low air velocity through the medium, typically 0.1 to 0.18 m/s. To be effective the fibres within the medium have to be very fine and relatively closely packed together. The fibre diameters therefore range from 4.5 microns to as low as 0.7 microns, the finer the fibre the more efficient being the filter medium.

Bag filters are available in a wide range of efficiencies. The most efficient of them, utilising the 0.7 micron glass fibres, when clean offers just over 70% efficiency against 0.3 micron particles.

As the filter collects dirt the entrapped particles act as secondary targets, capturing other particles in turn. Hence it is normal for the efficiency of a filter to actually increase as it becomes laden with dust. The increase can be substantial. In the case of the top grade bag filter the efficiency against 0.3 micron particles increases from 70% when clean to over 90% when dirty - a threefold reduction in penetration.

The bags are attached to a header which serves to keep the mouth of each bag fully open. The air passing through the bags inflates them, most designs of bag filter being designed to be self-supporting under operating conditions, even though they can be up to a metre long.

Early designs of bag filters had the bags glued to a header plate. But the art of successful bag filter design is to reduce pressure drop and achieve maximum effective use of greatest possible filter medium area. Headers are therefore now made to provide minimal obstruction of air flow into the bags, reducing entry pressure losses. The bags themselves are shaped and contoured, using variable span stitching, to stop adjacent bags masking each other. As many manufacturer has found to his cost, it is no good cramming more media into the filter in the hope that this will increase performance. If the bags fail to inflate, or interfere with each other the result can actually be a drop in efficiency and dust holding capacity.

At the bottom end of the efficiency scale low grade bag filters have all but made the automatic roll filter extinct. Bag filters can be purchased which offer a longer life between changes than most roll filters, a better efficiency, but at a fraction of the first cost of a roll filter. They are also simpler to maintain, not having any controls or moving parts.

HEPA FILTERS

Interception/diffusion is also the technique employed by the most efficient filters of all - HEPA filters (High Efficiency Particulate Air Filters). These utilise a glass paper medium formed from sub-micron fibres which is pleated to provide a high ratio of medium to face area. The pleats are held apart with corrugated separators, and the whole filter pack is sealed into a box casing.

Due to the high area of medium the velocity through it typically is only 0.025 m/s. Hence a standard HEPA filter has a minimum efficiency of 99.97% on 0.3 micron particles.

Development of VHSI (Very High Speed Integrated) circuits containing in excess of 256,000 memory bits on a single silicon chip has created the need within the microelectronics industry for super clean environments. These require the virtual total elimination of particulate contamination in order to maintain electrical isolation between conductor strips less than 1 micron in size. VHSI filters are available which have an efficiency better than 99.9995% on 0.12 micron particles. In fact the limitation is not so much filter design, but in the ability of measuring techniques - even the latest computer calibrated laser spectrometers - to determine the performance of such ultra high efficiency filters.

Recent years have seen the development of what is known as minipleat HEPA filters in which the closely spaced pleats are kept apart by ribbons of glass paper instead of conventional corrugated separators. This technique makes it possible to use more compact filters, which has been of particular value for clean room applications.

ELECTROSTATIC PRECIPITATION TECHNIQUE

The third and final air filter technique is that of electrostatic precipitation.

It relies on the attraction of charged particles to surfaces of opposite polarity. The particles are charged by passing the air between ionising wires which are fed with a high voltage d.c. supply. The air is then directed through a series of charged plates of opposite polarity to that given to the charged particles, so that they are attracted and retained by the plates.

With this technique efficiencies comparable with those of good bag filters can be obtained.

ELECTROSTATIC FILTERS

With the wet wash type of electrostatic filter the accumulated dirt is removed from the collector plates by a high velocity spray. Normally the unit has to be de-energised and switched off whilst the sprays are operating, cleaning being required at monthly intervals or less.

Alternatively the dirt can be allowed to build up on the plates, eventually forming agglomerates of such a size that they are blown off, to be collected by a secondary filter such as a bag filter. Not only does the electrostatic - bag combination provide an improved efficiency, it extends the life of the bags by a factor of 5 due to the large size of the agglomerates. Hence particularly for filters handling large volumetric flows this can be an attractive proposition.

There are filter materials on the market which are self-charging due to the application of a resin in the fibres. Great claims are made for these materials, but what the suppliers do not point out, for obvious reasons, is that if the relative humidity rises above 80% the charge is lost and the filter unloads its accumulated dirt burden. In our climate, with its fogs and humid days, the relative humidity often rises above 80%, so this type of filter medium is not to be recommended.

GENERAL

There is no ideal, all-purpose filter, hence there have been numerous type of filter developed, each with its particular range of applications.

As a general rule, higher efficiency involves higher pressure drops and hence increased fan running costs. In particular, higher efficiency tends to lead to a higher cost for the actual filter. It is therefore important, when selecting an air filter for a particular application, to look at all the relevant parameters, including:

1) efficiency
2) pressure drop
3) dust holding capacity
4) installed cost
5) replacement costs
6) maintenance
7) size of filter installation.

Incorrectly specified filters can be costly. It is therefore hoped that this brief discussion of air filter techniques will prove helpful towards formulating an understanding of how air filters function.

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INDOOR AIR QUALITY
ACCEPTABLE STANDARDS AND BUILDING DESIGN

THOUGHTS ON AVOIDING TROUBLE

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THOUGHTS ON AVOIDING TROUBLE

by
Roy A. Waller

INTRODUCTION

My involvement in the internal environment of buildings has been largely in a trouble-shooting capacity rather than in a design role. What I have done in the various situations where I've been called in is to try and diagnose the cause of the problem or problems. Often clients have spent quite a bit of time, and often quite a bit of money, in modifying or adjusting the building's physical systems - the ventilation systems, the heating etc - with no effect and sometimes with an adverse effect. The message that I want to put over this morning is that often these problems are not the result of one particular cause, but of a combination of causes and frequently of a cause which is non-physical. Where I am involved in this trouble-shooting role, I have always asked that I should have the authority to look at the situation as a whole, rather than just look at, say, the level of ventilation.

I would like to start off with an abbreviated check-list of some of the things that do go wrong in buildings. I will be looking at the majority of these in a little bit more detail and then at the end I will try and reverse the situation and say what can be done to avoid some of these problems.

CHECK-LIST

The first and most obvious thing is to see whether there is any particular **physical nonsense.** We have heard some examples of these already and I will show you one or two more. **Complaints procedures,** particularly in air-conditioned offices, are fairly important. It is often only via such procedures that communication with the management of the building is practicable and that people are able to control their environment. This is a very important factor when you are comparing an air-conditioned building with a conventional building, where people have windows, etc. that they can open.

Frequently, not so much whilst the oil price is relatively low, but certainly when oil was relatively expensive, a lot of the problems have arisen from the introduction of **energy conservation measures**, again without appropriate communication with staff.

There are, from time to time, problems with the **air supply**, or the lack of it. People have 'adjusted' the **physical systems** to the extent that they are no longer operating in a viable manner.

Then there are **historical factors** which perhaps I shall dwell on a little as I shall not be returning to them. It may not be very common, but if an organisation is moving from a conventional building into an air-conditioned building, this can give rise to very significant problems indeed. The tendency is for people to expect, in moving from an ordinary building to the modern air-conditioned building, that all problems will disappear and everything will be really perfect. Nothing could be further from the truth and this is a most unwise approach to take. There are problems with air-conditioned buildings, principally the difficulty of individuals exercising control over their own environment. These are disbenefits to be balanced against the benefits of air-conditioning. This must be spelt out to people before they move, otherwise their expectations will be so high that they will be disappointed.

This leads on to the **interaction between staff, management and unions** coupled with the question of communications in relation to complaints. The working of such social structures can influence the reaction of people to their physical environment. The design of the workplace, particularly in relation to VDUs, can create situations which result in complaints bound up with the physical environment. However, they may well be more to do with the **individual workplace** than with the environment of the building as a whole.

As we have heard already this morning, there are problems with the **contamination of the atmosphere** in buildings. I personally haven't really been involved in any case of serious indoor pollution. Certainly, using current levels of acceptability, there is usually nothing terribly serious in pollution terms, although hypersensitivity will result in some people being adversely affected by apparently quite reasonable levels of contamination.

So much for the general review. I shall now examine in more detail one or two of the common problems.

Physical Nonsenses

The first is a real example of a commercial tenant moving into a multi-storey building. Fresh air was brought in at the periphery of the building while within the centre or core of the building were the lift shafts and service ducts etc. The tenant company had its own ideas about partitioning. Unfortunately they were not compatible with the system of air-conditioning. As a result, some rooms had air supply but no extract, others had extract but no supply, others had neither. The occupants on the periphery of the building often opened the windows to allow stale air to get out. This unbalanced the whole system and even those rooms with a full complement of services went out of adjustment!

Complaints Procedures

My second point is about complaints procedures. There is a natural tendency on the part of owners and employers to ignore building complaints. The result is likely to be an increased determination and insistence by the occupants to regain more effective control of their immediate environment. If these complaints do not produce objective or subjective improvements, then the occupants feel out of control and they will become even more sensitized to the conditions.

Figure 1 shows some of the results of a survey in a large office building, all open plan offices designed on the same basis, but with different departments in three different areas. In the first two areas 20% - 40% of the staff were complaining, with about 40% regarding the environment as unsatisfactory and a low percentage, 20%, regarding it as comfortable and a variable percentage regarding it as stuffy.

Both were departments where the organisation of complaints was poor. In one, the departmemt manager insisted that all complaints go through him; he happened to be an individual who had extreme and fixed views about a suitable working environment, which I think it is fair to say none of his staff agreed with. They were all rather upset because they had no control over their environment.

At the other extreme, was the department (Area F) where the attitude was very relaxed and anyone who wanted to complain was perfectly free to do so. Complaints were passed on and building control specialists were brought in. All the group of about 15 employees had complained at some time about the environment but only 10% regarded it as currently unsatisfactory, while 70% regarded it as comfortable. (It is a slight digression to say that 70% also regarded it as stuffy, which suggests that stuffiness is not always a bad thing!). The point I want to emphasise is that, although there was an extremely high level of complaint, the fact that these complaints were dealt with sensitively and sympathetically actually resulted in the majority of the staff saying that they regarded their environment as comfortable.

Variability of people's sensitivity

We have heard this morning about the variability of people's sensitivity to various aspects of the environment, one aspect of which is the thermal environment. Figure 2 shows the percentage of people regarding the environment as comfortable in laboratory conditions. It is possible to maximise the percentage of people regarding the environment as comfortable at about 93%, but no better than that because about 3% of the population will regard any particular environment as uncomfortably cold and another 3% will feel it to be as uncomfortably hot. There is an optimum point beyond which it is impossible to improve, simply because people are not all the same.

There are other reasons why people do not react equally to the environment. Different activities generate different levels of heat; if you have people doing different things at various levels of activity in the same space there will be different reactions from people to the environment. Thus, as far as possible, activities should not be mixed in a space which has

one element of control. Different activities really need to be in different areas of the building with separate controls.

Fig 3 shows the optimum setting for the thermostat in a room as a function of the amount of clothing that people have on. For women in light summer attire the optimum setting is something like 75 degrees F, whereas for men wearing three piece suits, the setting is about 6 degrees F less. Thus, if ladies in summer frocks and gentlemen in three piece suits occupy the same space, their reactions will vary.

Without any ability to control their own particular environment, the percentage of people who will feel uncomfortable will rise.

Effects of Energy Conservation

Energy conservation is another cause of discomfort levels rising. In one particular office energy conservation was introduced without the knowledge of the management or the staff. The period between the point at which the heating system was switched on and the start of the working day had been reduced, so that it wasn't until about 10.30 am that the environment reached its designed temperature conditions. Then, depending on whether the system was switched off or allowed to overshoot, there would be a variety of temperature patterns at the end of the day. As if that wasn't bad enough, the building control engineers were told (again without anybody else knowing) that they should ignore all complaints before 10.30 am because there was nothing that could be done about them. The end result was a lot of frustrated people complaining with no reaction, either verbally or by way of a change in the physical environment.

Another consequence of trying to conserve energy is the reduction in the total amount of fresh, outdoor air. This is the simplest, easiest and cheapest method of reducing the total energy requirement of the building. The temperature of the outside air has to be brought up to the temperature of the inside of the building. In winter this will involve a lot of heating costs. Another measure is to switch off a number of the fans to reduce the amount of circulation, simply because the cost of electricity can be quite significant.

Air Flow

There are other causes of poor air flow. The utilisation of half-height partitions is likely to interfere with the original pattern of air distribution and to create many locations in which the ventilation efficiency is much lower. In many offices there is a tendency to erect, in effect, partitioned spaces within an open plan office and this can result in areas where the air velocity is low. The trend over the last decade or so has largely been to ensure that air velocities are not too high, in order to avoid draughts. However, my feeling is that many people prefer to have that certain freshness which is produced by air movement. As we have seen, measures to improve energy conservation tend to reduce air movement, leaving a number of people who find the environment uncomfortable simply because the air movement is too low.

Social Dissatisfaction

The same large office building where discomfort was surveyed was subject to a mild attack of the "sick building syndrome". There were a variety of factors involved. Although the building was designed to be uniform, in practice it was never built that way (the system was never completely balanced so that the flow of air and the temperature was the same everywhere; it varied in a somewhat random way). 12% of occupants reported discomfort and, perhaps more significantly, another 12% said they were dissatisfied with their environment, even though they were not uncomfortable. This dissatisfaction seemed to be compounded by dislike of an open plan office, and frustration at the inability to control the environment effectively. Complaints were not always dealt with in a way that people regarded as adequate and this resulted in further frustration. Thus, about half the total dissatisfaction was probably attributable to physical conditions, with the rest attributable to other things, which could be classed as being more social in character.

Social dissatisfaction can be ameliorated to some extent by

evidence of management taking the problem seriously. A serious evaluation taking place is seen by the occupants as evidence of their having regained some measure of control. A space with windows which can be opened by the occupants, or with an individual fan coil unit, has elements of controlability which are much valued by the occupants. There may well be cases where people prefer what to the building designers are seen as the discomforts of the conventional building, ie radiators and openable windows, windows that will help to control the thermal environment but posssibly let in noise. People may prefer that environment to working in a fully air conditioned environment, where they do not have any real degree of individual control.

Ergonomics

Another factor which can influence apparent satisfaction with the environment is the question of ergonomics which often gives rise to problems. The Association of Opthalmic Opticians stated that, "Working at a VDU will not cause eye damage but due to the concentrated effort required for the task, this can increase the awareness of existing eye deficiencies". It is certainly true that many people working at VDUs, particularly those who have glasses, but also those who don't, are not wearing the appropriate glasses for the task. A VDU is a rather special task and eyesight that may be perfectly good for most other purposes may not be appropriate for the use of a VDU. Many people who complain of dry or sore eyes may simply need to go and have an eye test and get a different pair of glasses, or indeed get a pair of glasses in the first place. With both social and ergonomic factors, people find it very difficult to identify what really is their problem and they tend to transfer their dissatisfaction to something more obvious, complaining that, "It"s too hot, it's too draughty, it's too noisy". It is much easier to make such complaint than to say, "I don't like the manager" or "I don't understand what's happening".

CONCLUSIONS

I have talked about the variety of problems. It is perhaps less easy to say what should be done about them when designing or re-furbishing a building. There is a strong suggestion, not as yet proven, that one of the ways of avoiding the sick building syndrome is to maximise the amount of fresh air. A sick building is less likely to develop where the fresh air levels are high than where most of the air is re-circulated. I would add that I think that we want to ensure that the air is kept moving. Draughts should be avoided but on the other hand the air should not be so still that it is regarded as stagnant.

I have not discussed humidity but I believe that we need in general to maintain rather higher humidity levels than are the norm in this country. People often switch off the humidity control on the basis that the level is about right naturally, so the control can be turned off to save energy. However, I suspect that there are genuine humidity drops and people suffer as a result.

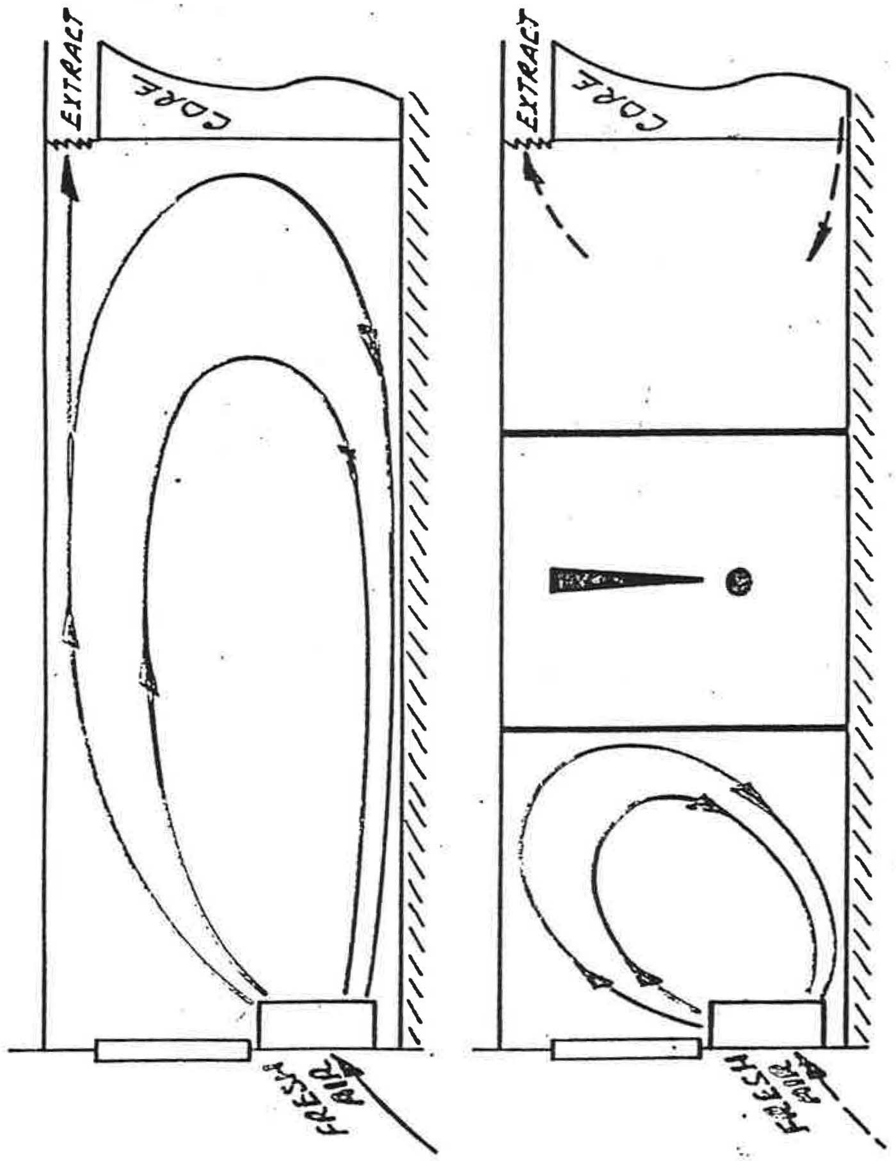
People like to feel that they have some control over their environment, preferably physical control. If they do not, then there must be some control through the communication/management complaints procedure; otherwise there will be trouble.

Another matter to be considered is the introduction of smoking policy: this should not be done without considering the ventilation system in the building.

To sum up, the success of a building in terms of a general absence of problems, will depend not only on the building designer but equally on how the staff and the management get on together and how, together, they use the building.

CHECK LIST

- PHYSICAL NONSENSES
- COMPLAINTS PROCEDURES
- ENERGY CONSERVATION
- FRESH AIR SUPPLY/AIR FLOW
- ADJUSTMENT OF PHYSICAL SYSTEMS
- HISTORICAL FACTORS
- STAFF/MANAGEMENT/UNION INTERPLAY
- ERGONOMICS
- CONTAMINATION OF AIR



	AREA Δ	AREA E	AREA F
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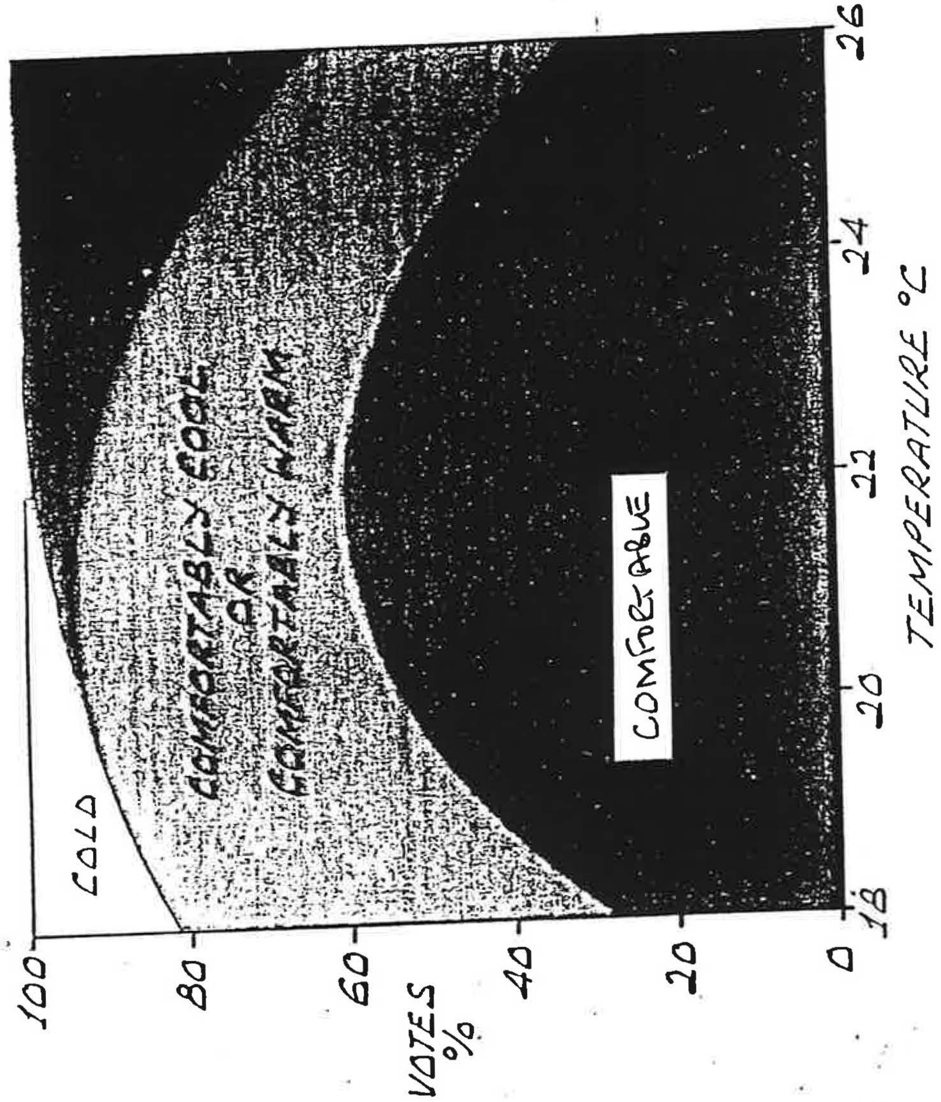
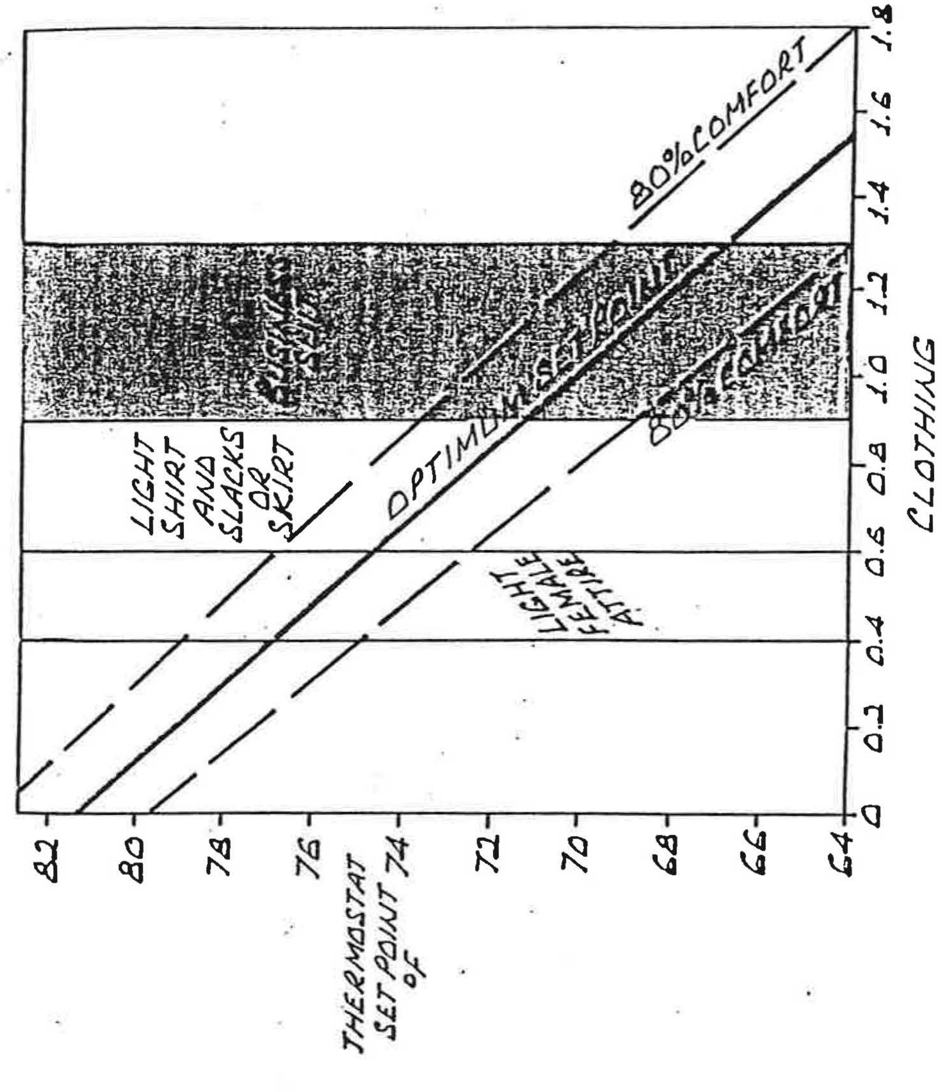
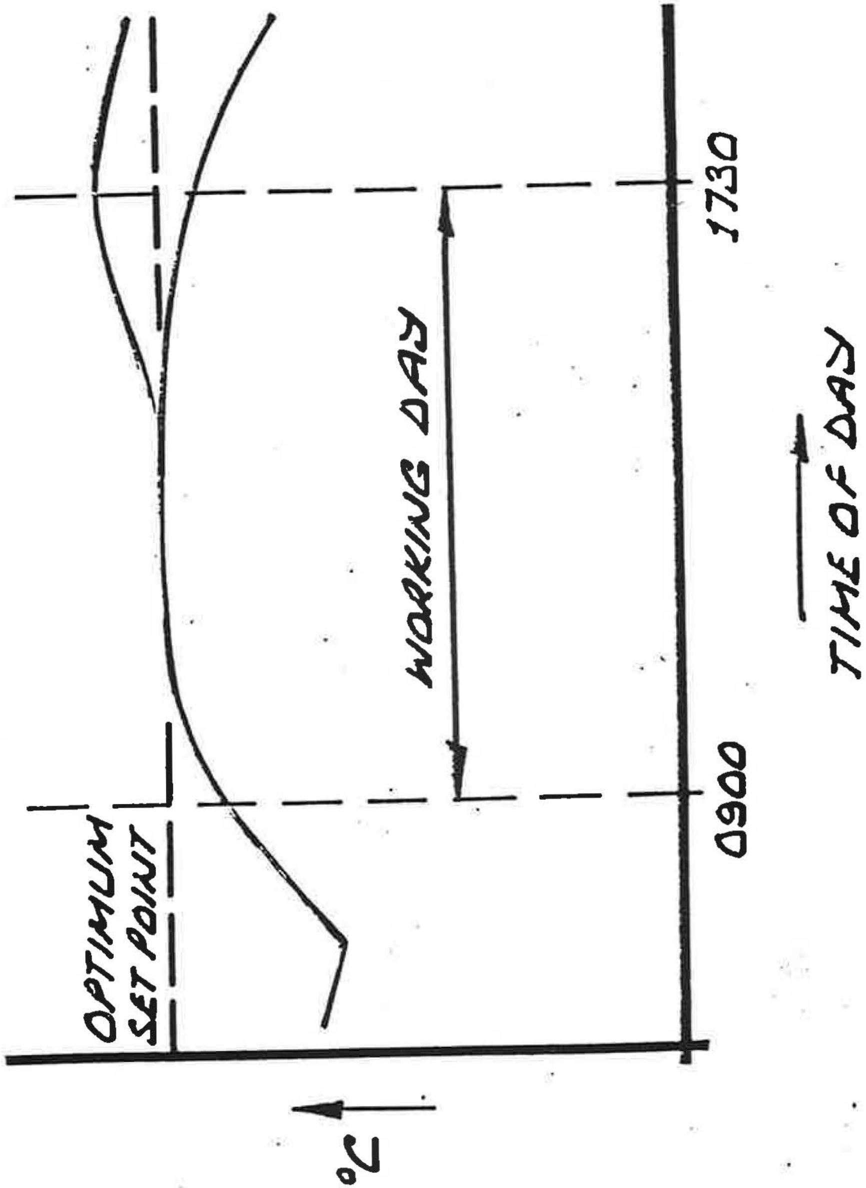
UNSATISFACTORY	40	40	10
COMFORTABLE	20	20	70
STUFFY	60	30	70


COLD
COMFORTABLY COOL OR COMFORTABLY WARM
COMFORTABLE
TEMPERATURE °C
18
20
22
24
26
VOTES %
0
20
40
60
80
100


80% COMFORT
OPTIMUM SET POINT
80% COMFORT
LIGHT SHIRT AND SLACKS OR SKIRT
LIGHT FEMALE ATTIRE
CLOTHING
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
THERMOSTAT SET POINT °F
82
80
78
76
74
72
70
68
66
64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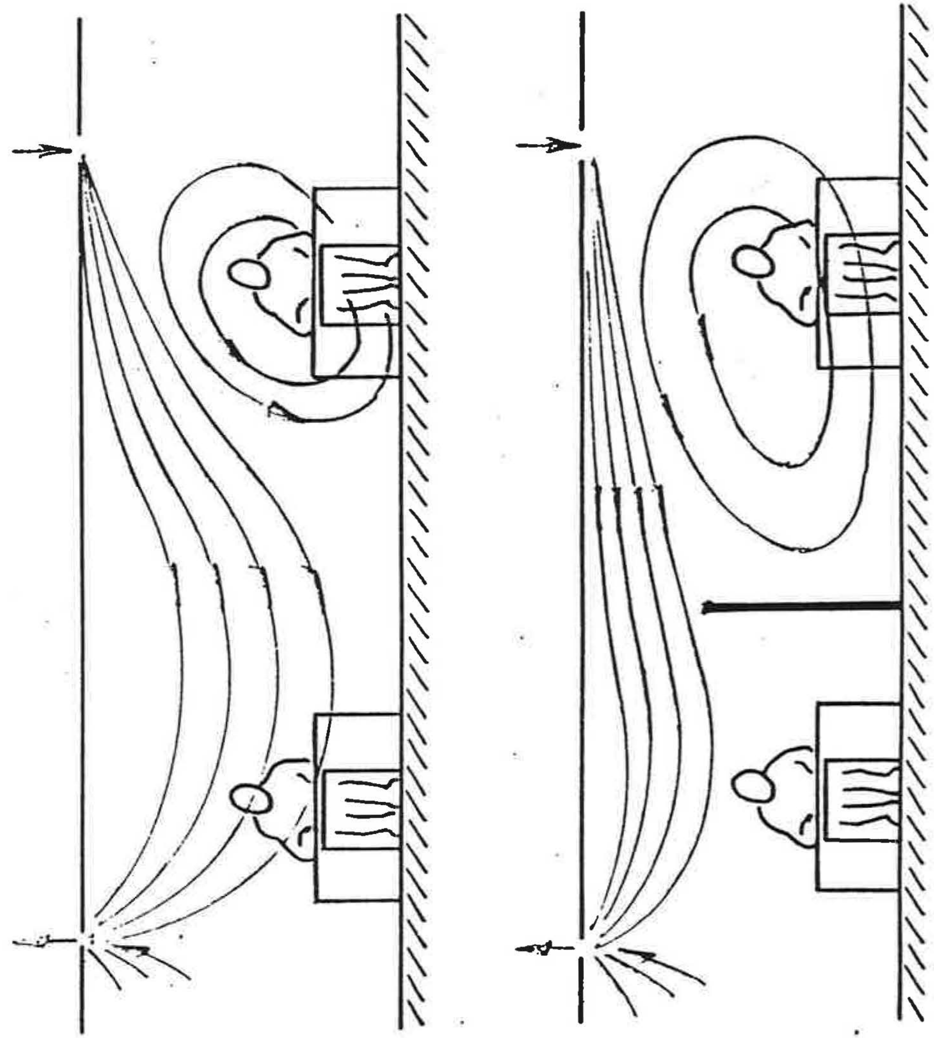
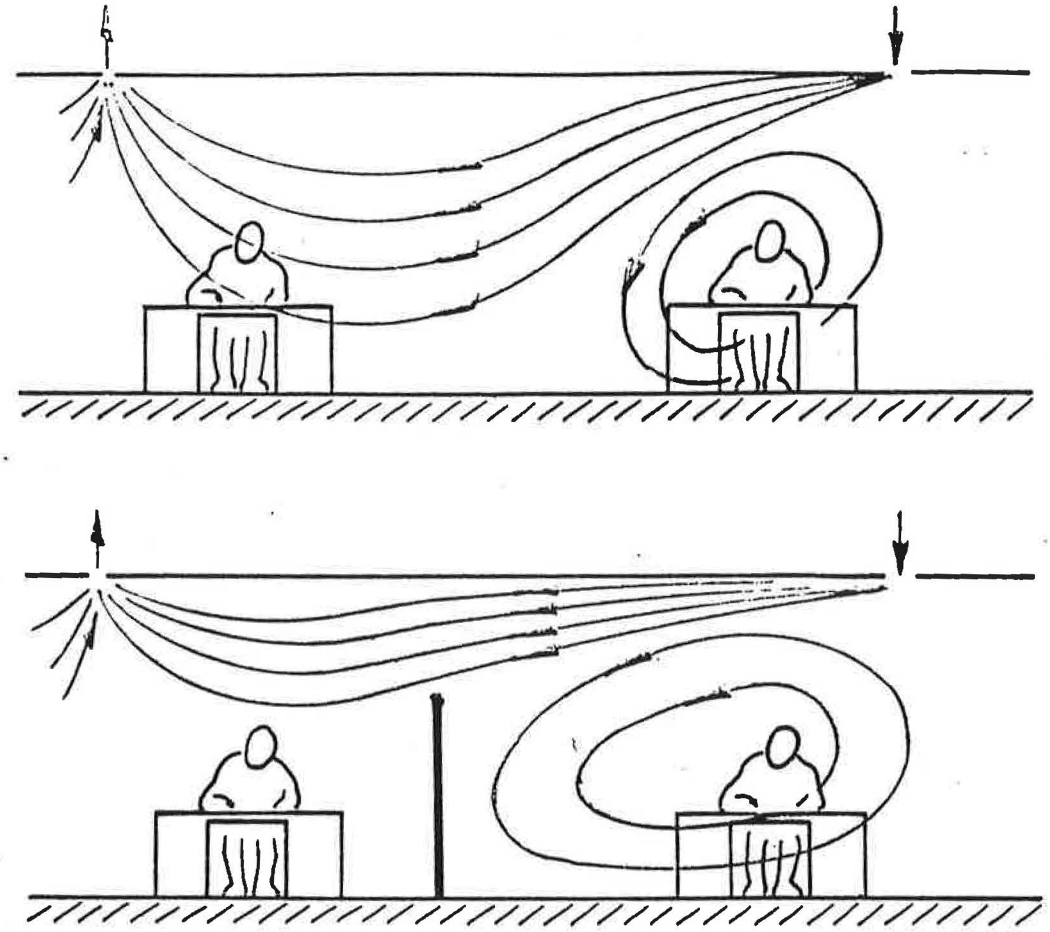
SET POINT
WORKING DAY
0900
1730
TIME OF DAY
°C





PRACTICAL MINIMUM DISCOMFORT	7%
	+5%
ACTUAL DISCOMFORT	12%
	+12%
ACTUAL DISATISFACTION	24%

CHECK LIST

- o MAXIMISE FRESH AIR
- o KEEP AIR MOVING
- o KEEP UP HUMIDITY
- o REMEMBER ERGONOMICS
- o PROVIDE CONTROL/COMMUNICATION
- o CONTROL SOURCES of POLLUTION
- o THINK BEFORE CHANGE

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INDOOR AIR QUALITY
ACCEPTABLE STANDARDS AND BUILDING DESIGN

CONCLUSIONS: POLICY AND PRACTICE GUIDELINES
by

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CONCLUSIONS
and
POLICY AND PRACTICE GUIDELINES

by
Steve Curwell

I notice from the delegates list that many of you are from local authorities; while I am bound to concentrate on building design issues I shall attempt to outline policy and practice guidelines that could be adopted by local authorities. I hope that I shall stimulate debate during the final discussion period. I should also make it clear that while I speak as an architect, which I hope enables me to give a general overview, I am not a building services engineer, so you must excuse me if I tread on any corns. Nor am I a health expert, and any advice I give should be qualified by others with the appropriate expertise. I agree with Chris March that people should not drift into other professional areas on the basis of a half-knowledge.

I should like to start by praising the quality and quantity of the information which has been presented during the Workshop. As I sat down last night to pull the strands together for this summary, I found I had a mass of papers to go through; but I thought it was worth attempting to clarify the situation and some of the data. Some was specifically related to main topic areas and I hope to highlight the main points for design practice standards. Apart from the specific presentations on car parks and on dry cleaning establishments, little of the information was related to particular building types. On occasions we discussed ventilation in broad terms and I should like to stratify my talk by looking at particular purpose groups or applications. First, I think a useful distinction can be drawn between housing and lot of the other building types, principally because houses currently operate on a passive ventilation system: they are naturally ventilated, and the vast majority of other buildings, even those of a naturally ventilated type, are normally supplied with some mechanical ventilation to central areas, cores and other facilities. Beyond that, with commercial deep plan arrangements, air conditioning has obviously been very popular.

Beginning with domestic buildings, which I know most about, and particularly as Chris March and I have been researching into this area, it seemed to me that several speakers were looking for guidance. The question of what are safe levels of various contaminants was raised on several occasions, and a knock-on question is what is a safe minimum ventilation rate. I shall try to identify some ventilation rates and commit myself, and perhaps the rest of us, to going away with some figures in our minds. But before coming to that, we should perhaps recall that both Derek Gregory and Andrew Warren both urged us to concentrate on an appropriate air change rate with energy considerations in mind. This involves some unavoidable fundamental physics. If buildings are insulated to a high level, then ventilation and infiltration become the most significant sources of heat loss. Andrew Warren in his talk did I think miss that point, and consequently failed to draw the conclusion that if we go for low energy buildings and reduce ventilation rates more and more, then we are inevitably creating health risks. It is essential to control the ventilation and infiltration rates so that an economic return on investment in insulation is obtained. Sometimes control of infiltration rates is necessary to give perceived comfort conditions. When Victorian buildings are refurbished, double glazing is put in, not as an energy saving measure, but primarily to reduce draughts from sliding sash windows.

Derek Gregory mentioned that the Scandinavians have reduced ventilation rates, and studies I have looked at show air change rates as low as 0.16 air changes per hour. Now, as far as I am concerned, this is entirely an infiltration rate, given a timber-framed construction with lots of membranes in the construction. It is worth drawing a distinction between infiltration rates and properly designed, provided ventilation, because excessive infiltration in any building design will upset the design, particularly the balance of the mechanical arrangements. This difference needs to be appreciated.

I agree with Derek Gregory that if we import such low

infiltration rates from Scandinavia, we need to bring in appropriate ventilation techniques for housing; the main reason for this obviously is to reclaim energy, so that it is not simply thrown away by opening windows.

For the domestic situation my understanding is that there is at present no really efficient heat reclaim arrangement, the expense of which can be justified at present in terms of a sensible economic return. Therefore, in the short term anyway, we must accept that with well insulated and sealed housing there should be additional ventilation on top of the residual rate from infiltration.

Looking at the infiltration rates we actually have in UK housing stock at present, I would refer you to studies by Warren & Webb, which were reported in our book on "Hazardous Building Materials". These suggest infiltration rates of about 0.7 air changes per hour. I suspect that the latest designs will be more tight than this, because they will have high performance windows and other features which were not necessarily a feature of the Warren-Webb studies.

In the book we have developed the concept of air change rates, from the minimum requirements, to those necessary to satisfy other performance factors, particularly control of condensation and other indoor pollutants generated during the normal in-house activities - cooking, respiration, washing etc. From that, it is generally accepted that a ventilation rate in houses between 0.5 and 1 air changes per hour is satisfactory. The infiltration rate figure from the Warren Webb studies seems to agree with that, and we can assume that with an air change rate of about 0.7, condensation can be satisfactorily controlled without taking any extra measures - assuming satisfactory levels of insulation in the structure.

If the aim is to achieve more sealed buildings, on energy conservation grounds, then that will imply the introduction of additional ventilation measures which, for houses, will be natural ventilation. Building Research Establishment Digest 210 gives the principles of ventilation but provides no firm guidance as to how big opening sections of windows should be and what sort of reliable ventilation rate will result, simply because knowledge in this area is small. At present there is no analytical procedure for designers to follow in thing but for those who have just bought the latest type of house and are intent on adding draught stripping to an already well sealed place, I have worries. Which magazine and similar sources of advice should first tell people to attempt to analyse the ventilation characteristics of their dwelling, and caution that if the building is already well sealed, then perhaps draught stripping may be unnecessary and even counterproductive in environmental terms. Many people simply do not understand that they are already living in well sealed homes. My advice on draught proofing a window is usually "three sides on, one side off". It is very simplistic and probably cannot be related to any sensible ventilation rates but it makes me feel better, in that it is providing a minimum amount of ventilation.

Roy Harrison raised a point also very close to my heart, about paint stripping and the elevation of lead levels in household dust particularly after sanding down heavily leaded paints. I wish to add a cautionary note to what he said, specifically that while blow lamps heat the paint to a high temperature and obviously cause vaporisation of the lead and therefore a direct inhalation risk, the hot air blowers, which many people think of as being a low temperature device, may also attain temperatures sufficiently high to vaporise the lead in paint. In the wrong hands the hot air blower can be dangerous. And while Roy Harrison rightly said that sanding creates the main risk from the dust point of view, it is a case of swings and roundabouts: the solvents in paint strippers create another set of risks. An important point about the whole issue of hazardous building materials is that it is often all too easy to exchange one set of risks by changing from one material to another; the solutions are not always as clear cut as you think.

As to hoovers and whether they are effective in removing dust, the advice given is that the right machine, ie one capable of removing asbestos fibres, will collect most of the other dust. However, with other machines the action of the vacuum stirs the dust around so much that Roy Harrison's worry about re-suspension would be intensified.

The whole of refurbishment is interesting, particularly when you consider that as a result of DIY activity the occupant starts to suffer the risks of being the operative.

Turning to the other buidling types, for commercial and assembly usages, I think Mr. Waller's talk raised the main points, but again it should be remembered that the higher levels of insulation currently incorporated in the building fabric with a reasonable area of glazing, will produce summer overheating. That is why air conditioning is so desirable, and why it is used in deep plan as well as many ordinary office arrangements, to give cooling in summer. Dr. Pickering questioned some of the accepted wisdom about air conditioning, particularly whether humidifiers are necessary. In contrast, I was interested in Mr. Waller's point that he felt humidity levels were not high enough. As an architect trying to make design decisions, I still do not really know which way I should be facing on this one.

One of the important points to emerge from Dr. Pickering's talk is that if you can avoid cold water spray type humidifiers, you will be avoiding a double edged problem: the first being the potential disease risk of the equipment and the other being the biocide required to control this potential risk. The other point that I have taken on board in design is that the cooling towers must be positioned well away from air intake. This may seem obvious, but when you are involved in a very complex building design, some of these important environmental factors get forgotten in the face of the many other problems that must be tackled. I can understand why, occasionally, people offend against that simple rule in their design. I have great sympathy for the heating and ventilating engineers who are trying to cope with these difficult problems.

Chris March referred to the British Property Federation as major commissioners of buildings and I see local authorities as being another major sector. I put it to you, are Environmental Health Departments consulted about some of the issues we have been discussing, when buildings are being commissioned? Throughout my experience of working in building design, I have never had an Environmental Health Officer sitting next to me when we have been going through briefing sessions, and I think that requires reconsideration in the local government context.

heating which burnt the fuel and dumped the exhaust gases straight into the building. That should not be done in a small, unventilated building. The aim should be to ensure that the ventilation system within the building could cope with the use of a direct fired air heater. If carbon dioxide levels were allowed to rise above quite low values, health effects, e.g. lethargy and a general feeling of malaise, would be produced. Carbon dioxide levels were also good indicators of odour problems but could not be used as a monitoring tool if unvented heaters were already present.

Systems were currently being installed to modulate the fresh air intake into a building in response to sensors giving readings of carbon dioxide levels. These were currently expensive and had been used only in large institutional buildings but they could be applied to the factory situation. Thus, if large numbers of direct fired air heaters were used, it would be sensible to install a controlled fresh air system linked to sensors detecting changes in CO_2 levels. As these came into wider use, the cost would presumably decline. Dr. Gregory also thanked Mr. Cook for raising the point about ammonia, which he would certainly take into consideration in future.

DR. JEAN MONRO (Lister Hospital) had been most interested by Chris March's presentation, and considered that the book, "Hazardous Building Materials", would be a most interesting addition to the repertoire of material available to those affected by pollutants generated indoors. Referring to Dr. Gregory's remark that standards might be necesary for ventilation, Dr. Monro said that in her view the biggest problem was pollutants generated by things put into buildings: building standards could only deal with half the problem. Given an acceptable ventilation standard for the construction of the building, it would still be necessary to alter the ventilation rate in order to cope with the out-gassing from soft furnishings etc. Thus, the standard setting exercise could become very complicated. She advocated flexibility instead.

DR. GREGORY agreed with the point and said that the aim at BRE, BSRIA, etc. was to establish a minimum fresh air intake requirement for different types and uses of buildings. That approach seemed preferable to attempting to set

standards for maximum levels of pollutants in the building, or egress of pollutants from sources within buildings. Thus, it was hoped to arrive at guidance on minimum levels of fresh air that should be brought, by design, into various types of building, perhaps assuming a worst case scenario. Nevertheless, he agreed that it would be extremely difficult to take account of unpredicted uses of the building or the presence within it of unknown toxic substances. There was still not enough known about the release of toxic chemicals from soft furnishings, for example.

MR. M. E. COOKE (Leicester City Council) had some comments on Andrew Warren's presentation, which would take the discussion slightly beyond the Workshop's remit but were nevertheless of interest. He had been surprised that Andrew Warren had not mentioned Combined Heat and Power as a lower cost method of generating energy, in the context of discussing energy conservation. Mr. Cooke thought that CHP was particularly relevant to poor households, because it seemed rather ridiculous to concentrate solely on energy conservation investment in terms of the individual property which, for low income households, many of whom are Council tenants, meant that the occupier had no particular interest in investment to improve the value of the property.

Secondly, looking at the question of low income in relation to affordability of heating, Mr. Cooke considered that there was a strong case for grants to be made available to provide insulation in low income homes. Grants were available where people, usually better off, wished to improve their old properties and on that basis he considered that the Government should make grants available for proper insulation aimed at conserving energy and reducing fuel bills, particularly for the poor and elderly.

ANDREW WARREN acknowledged that, coming from Leicester, Mr. Cooke would have a particular interest in CHP and he regretted that it had been one of a number of aspects that he had been unable to include in his presentation because of lack of time.

Secondly, he entirely accepted Mr. Cooke's point about low income households, although he also considered that many of the perhaps apparently better off owner occupiers could also gain substantially through investment in energy conservation measures. For example, in Sheffield the Neighbourhood Revitalisation Scheme, aimed at providing better insulation against heat loss and energy waste, was almost entirely directed at owner occupiers. Nevertheless, approximately two thirds of the fuel allowances were paid to council tenants, hence investment in energy conservation measures could be of substantial benefit to the public purse. Moreover, a number of council tenants, despairing of any action by their landlords, were prepared to carry out some measures themselves aimed at improving comfort levels in the home and saving energy.

The Association for the Conservation of Energy had just completed a publication for the Department of Energy, which had been carried out in conjunction with the National Housing and Town Planning Council, on publicly owned housing and energy conservation - covering both council housing and housing association-owned homes. Because of the source of funding, it had been difficult to make a specific recommendation about grants, which had been written into the original draft and was subsequently removed. Nevertheless, he considered that there was a more general recognition now that the deliberate exclusion of insulation measures from the Home Improvement Grant had been a mistake. The assumption had been that, since Home Insulation Grants existed, it was sufficient to cover the matter. However, those grants of course only applied to loft insulation and hot water tank insulation, and the plan was to phase them out until they would only be available to people living on supplementary benefit.

MR. R. HANLON (Belfast City Council), commenting on Dr. March's paper, said that in his health and safety role he had frequently written to manufacturers of building products, etc, requesting data sheets, which were almost invariably found to be next to useless. It was very difficult to get proper information about the contents of building products, although such data were required in order to make some assessment of their implications for health and safety. He believed that some statutory requirement to furnish information of that sort was essential. After all, these were only one potential source of toxic materials in the building, and an unknown cocktail effect could be produced unless

proper information on constituents of products, fittings and fixtures as well as the emissions from various processes within the building was available.

CHRIS MARCH agreed with all those points and said that from the designer's point of view, the problem was even more complicated. The hazardous building materials project undertaken by Chris March and Steve Curwell was actually just the tip of the iceberg; to do the job comprehensively would require approximately 25 volumes of information and data sheets. At present, designers could not obtain such information unless manufacturers were prepared to disclose it, which they usually were not.

DISCUSSION - SESSION 3

Speakers: Mike Squirrell and Dr. Roy Harrison

DR. CHING AW (Universty of Birmingham) said that as an occupational physician, he could suggest at least one other way in which lead dust or indeed other metallic dust could enter homes, and that was from the workplace. Studies had shown that workers could bring both asbestos and lead dust home from the workplace on their clothes. This was either due to a lack of washing and changing facilities at the workplace, or non-usage of these facilities when provided.

Secondly, Dr. Aw had a question for Mike Squirrel. Referring to the two slides he had shown giving concentrations of various substances in sidestream as opposed to mainstream smoke, Dr. Aw highlighted the great variation in amounts of these various substances. He asked for some explanation.

DR. R. HARRISON welcomed the point about dust brought home on workers' clothing. An important study in Birmingham had highlighted the problem in relation to lead dust and had shown that this route produced quite significantly elevated blood levels. He thought it would be interesting to study the exact pathway of lead from contaminated clothing to children. That might tie in nicely with the hand-to-mouth and re-suspension pathways. However, the problem had never been studied in such depth since remedial action had been taken promptly in order to remedy it.

MR. M. SQUIRRELL speaking also on that point, said that Leeds Environmental Health Department had carried out a large survey of houses in Leeds, in which had been included houses occupied by workers at a local secondary lead smelter. That survey had revealed that, over the two or three hundred houses involved, by far the highest levels of lead in dust were in older houses with old lead paint.

Turning to the question about the main reasons for the differences between the levels of various constituents in mainstream as opposed to sidestream cigarette smoke, Mr Squirrell said that three factors were involved. The first was temperature; mainstream smoke was produced at a much higher temperature - 900 degrees C as opposed to 600 degrees C for the smouldering which produced sidestream smoke. A second factor was the reducing atmosphere produced at the tip of a cigarette, resulting in the greater quantities of chemical pollutants normally present in a reducing as opposed to a well oxygenated environment. Thirdly, the type of tobacco was a very important factor.

MR. G.W. BARRETT (Central Electricity Generating Board) said that Dr. Harrison had given a good deal of data on lead and had referred to the paucity of data on other metals. However, he wondered to what extent the data on lead could be extended to other metals, particularly perhaps to cadmium.

DR. HARRISON said that the lead data could not be extended directly to cadmium. The lead data was illustrative of the sorts of processes that were important in terms of influencing airborne metal concentrations within a building. The same processes would be operative for cadmium, although he suspected that the re-suspension factor could be different. The size distribution of cadmium in surface dust was probably different from that of lead. Cadmium was associated to a much greater extent with large particles and less with fine particles. Thus, while lead was useful to illustrate the processes involved, it would be wrong to translate directly from lead to, say, cadmium and extrapolate concentrations on that basis. There was a need both for more study of the processes involved and for more data on other metals.

MR. A. K. THORNE (Honeywell Control Systems Limited) asked for Mr. Squirrell's comments on the efficiency of electrostatic precipitators. He admitted to a vested interest, since his company manufactured such equipment. Mr. Squirrell had stated that the more air pushed through electrostatic precipitators, the lower their efficiency. While Mr. Thorne agreed with this point, he said that when used according to manufacturers' recommendations regarding air volumes, and as measured by the ASHRAE dust spot method, efficiencies of 95% removal of all particulate matter were achievable.

MR SQUIRRELL questioned the usefulness of dust spot measurements when applied to very small particles, eg those present in tobacco smoke.

MR. ANDREW WARREN said that Mike Squirrell had proved beyond peradventure that for both active and passive smokers, nicotine or tobacco smoke was dangerous. However, he wondered whether Mike Squirrell was prepared to go beyond his scientific researches to some serious recommendations as to how to overcome the danger. He believed Mr. Squirrell had touched upon this policy aspect, and then withdrawn. Fundamentally, the answer seemed to be to ban cigarette smoking, but it was difficult to see how this could be achieved in a liberal society. He did not consider the analogy drawn in Mr. Squirrell's paper, with the prohibition of drink, was quite fair. The great distinction he would draw between alcohol and nicotine was that alcohol was frequently an enhancer of social occasions - many people became somewhat nicer after a drink. On the other hand, they did not become more pleasant when they smoked nicotine.

MR. SQUIRRELL said that he was not sitting on both sides of the fence but he did not see how it would be possible to ban cigarette smoking completely. Clearly it would be most desirable to bring in legislation to protect people in the workplace and in public places but in practical terms it would be impossible to legislate against tobacco smoking within peoples' private homes. As to modifications in cigarette design to try to eliminate the serious pollutants, he explained that attempts had been made to insert an activated carbon filter into a cigarette. That had substantially reduced the toxic substances reaching the smoker direct, but had little effect on the constituents of sidestream smoke. Finally, if cigarette smoking was ever banned in this country, Mr Squirrell was sure that the tobacco industry would simply expand into another market, as is already happening in China and in underdeveloped countries of Africa.

MISS J. DUNMORE (NSCA Deputy Secretary General) asked Roy Harrison whether frequent vacuuming in the home, in an attempt to control lead dust from eg a nearby busy street, was useful or whether it would actually lead to re-suspension of lead dust as did sweeping.

DR. HARRISON said it was a very difficult question to answer in the absence of experimental measurements. He suspected that a good vaccum cleaner would be a fairly efficient collector of dust, although without experimental measurements he could not be certain of the extent to which a vacuum would trap the dust which it managed to suspend.

THE CHAIRMAN, MR. W.F. SNOW, asked Mike Squirrell whether his authority had taken any action to deal with passive smoking in the Council's own offices. A number of authorities had taken such action, and had also banned smoking in Committee meetings.

MR. SQUIRRELL said that Leeds City Council is developing a policy on tobacco smoke within Council owned premises. However, the procedure is very slow. It was necessary to get the backing of both elected members and the unions. There had been no real opposition from smokers as such, some of whom had welcomed the policy as being of positive help to them in breaking their habit. Many smokers, indeed, disliked working in a smoky environment.

Leeds City Council were also considering re-investing some of their superannuation funds: at present a small proportion is invested in tobacco.

DISCUSSION - SESSION 4

Speakers: Mr. B.W. Lawton and Dr. Ching Aw

DR. JEAN MONRO (Lister Hospital) asked Dr. Aw whether he had noticed any health problems in those people exposed to perchloroethylene. Some of her patients had exhibited noticeable symptoms in a similar situation.

DR. CHING AW said that he had questioned his sample of residents about their experience with a range of symptoms which he believed to be relevant to organic exposure. Approximately one third of the people questioned said that they had experienced a combination of symptoms. However, as noted in his paper, when those with and those without symptoms were examined, there was no correlation with perchloroethylene levels. In the questionnaire there had been a question about the recent state of health of the individual, ie whether the person had experienced any recent illness about which they had consulted a doctor. There was no association between the number of people reporting illnesses and perchloroethylene levels, although the number of people involved was very small.

DR. MONRO wished to make some comments on four or five of her own patients. One was a lady who lived above a dry cleaning shop; within eight weeks of occupying that new home, which actually overlooked the dry cleaning shop, she had developed multiple sclerosis. Much of the effluent from the shop was not vented through a proper chimney. She had been thoroughly tested by being put into a very clean environment and then, after five days, exposed to a very tiny test dose of organic terpenes, upon which she had become extremely ill, with an acute attack of dizziness lasting about twenty minutes. Thus, this patient had proved to be highly sensitive to levels of organic terpene well below those normally regarded as acceptable.

Another patient, a doctor from Nova Scotia, had become sensitised by leakage of perchloroethylene from a local factory which had somehow entered the drinking water of his

town. He was one of a number of casualties. He had developed a prolonged illness, a bit like glandular fever, although glandular fever had never been identified in him. He had only just been able to return to work, part time, two years after developing the illness.

A third patient actually owned a dry cleaning establishment and for ten years had experienced serious migraine attacks, until finally at the age of 45 he experienced haemaplegic migraine, which resulted in paralysis down one side of the body. His blood had proved to contain high levels of dry cleaning solvents. These had been estimated using a combination of gas chromatography and mass spectrometry. Dr. Monro said that she sometimes routinely tested patients for dry cleaning solvents, as well as for toluene and xylene, and had found that amongst people whose clothes were regularly dry cleaned there were measurable levels of perchloroethylene and trichlorethylene in their blood.

DR. CHING AW said that although he did not know of any particular proven connection in published literature between exposure to perchloroethylene and multiple sclerosis, he believed that any situation such as that of perchloroethylene leaking into the drinking water supply, should be remedied as a matter of urgency, without necessarily waiting for reports of ill health. The aim should be to take preventive or remedial action <u>before</u> people became unwell.

MR. G.W. BARRETT (Central Electricity Generating **Board**) said that a great deal of work had been done on low frequency noise in the range 30 to 200 Hz. Noise of that wavelength was known to induce a variety of symptoms, from disturbance in sleep through to nausea in certain people. A good deal of work had been conducted in this area at Chelsea College, by Leventhall and his assistants, with financial support from the CEGB. These studies had revealed that in about 50% of cases the problem was not low frequency noise but one created within the individual, either a disability within the hearing mechanism or a psychosomatic effect, or perhaps presbyacusis. But for the other 50% of people, the low frequency problem was very real and induced either outside the building or within its structure.

There were two possible avenues of control. The first through room design, since in many cases low frequency noise problems were greatly exacerbated by resonances within the room. Secondly, control could be achieved by examining sources of low frequency noise within dwellings, particularly the heating and ventilating systems.

The NSCA had worked to bring about an extension of the Building Regulations to control noise in various ways, the latest being to extend sound insulation measures to flat conversions. Mr. Barrett wondered whether the Building Regulations could be extended to secure control of the low frequency noise element, either through room design or through control and specification of sources, such as the heating and ventilating systems, and their low frequency noise content.

MR. B. W. LAWTON said that he had himself undertaken projects on low frequency noise and it was an area close to his heart. Sources of low frequencies in buildings were usually associated with very large heating/ventilating systems. The ventilation shafts would be meters long, with the resonance system created by the long length of ducting. Given a broad band noise input, the long duct would resonate like an organ pipe, at its favourite frequency, which would be very low because the duct was very long. The system would dump the energy out into the room, which also had its own resonance frequency, so that with certain types of ventilation systems people could effectively be working in the middle of a resonance chamber. He suggested the analogy of blowing across a beer bottle, which would produce a nice pure tone, but living inside the beer bottle at the same time would be highly uncomfortable. Inside the resonator one would be constantly exposed to very low frequency noise which, at high levels, could have quite drastic effects, such as nausea and disorientation.

It should be borne in mind that if a wavelength of a low frequency sound of, say, 100 Hz was 3.3 m then fibreglass insulation of six metres depth would be needed to absorb the frequency. Thus it was very difficult to design effective controls against low frequency noise in buildings. It was quite impractical to absorb the noise within the duct. Again, if the aim was to keep that type of low frequency

noise out of the building, then the facade of the building had to have great mass - eg 1 m of concrete in thickness.

But as to Building Regulations, Mr. Lawton found it difficult to imagine that any regulations could be framed so as to deal with lift shafts, which were long and rumbly, eg by requiring them to be mounted in a bed of sand with 1 m thick of concrete to retain the low frequency sound. In most circumstances the problem would simply be diverted over the building onto someone else's property. The problem was one of physics, which could not be legislated away. It was neither practicable or economic to try to attenuate low frequency noise sources.

Taking a mischevious dig at the CEGB, Mr. Lawton pointed out that there was a trade off between the benefits of dispersing the combustion products from fossil fuel power generation through a very tall chimney so that the pollutants would fall out on Scandinavia (if that was current policy), and the resultant creation of a prime low frequency noise source - the chimney itself. This would fill the surrounding county with low frequency noise at whatever the particular resonant frequency was. One environmental solution (if such it could be called) was thus generating another environmental problem.

DR. DEREK GREGORY (Building Services Research and Information Association) wished to comment on the perchlorethylene problem. Dr. Aw had been concerned that the vents from the dry cleaning establishments had been routed very near to the windows of the flats above, but Dr. Gregory pointed out that the ducts were doing their job in by-passing the window; without the ducts, the fumes might enter rooms via the window. Clearly, however, there would be cause for concern if the duct was leaking.

In the pictures Dr. Aw had shown, it was clear that the duct terminated at the eaves of the building. Dr. Gregory pointed out that had it been a boiler flue, Building Regulations would have required the flue to be taken up towards the ridge level of the roof rather than terminating at the eaves. In the case of an industrial flue carrying a toxic element such as perchloroethylene, there would be a requirement for periodic inspection to guard against any leakage from the duct. But neither of these requirements seemed to apply in the case of ducts serving dry cleaning establishments.

One course of action might be for local authorities to press for these ducts at least to be treated on an equivalent basis to chimneys serving domestic boilers. After all, it was not possible to terminate a balanced flue, which did not go up through the roof but came out through the wall, closer than 2 feet from the window because of Building Regulations. Perhaps it might not be unreasonable to ask that dry cleaning ductwork should be routed at least 2 feet away from windows. Different standards appeared to apply, even though perchloroethylene was clearly as unpleasant and toxic in its effect as carbon monoxide or other combustion products from heating boilers.

MR. I.W. BARKER (NSCA Chairman) said that some twenty years earlier as an EHO in Leicester he had dealt with very similar premises, with the same inadequacies in maintenance as had been revealed by Dr. Aw's slides. He found it sad that after a lifetime's work in environmental health, very little appeared to have changed.

There were literally thousands of Victorian/Edwardian premises with accomodation above shops which had originally dealt in non-toxic goods and services. Because of a defect in the planning laws in the 1960's, coupled with a change in technology, there had been an upsurge all over the country of coin-operated launderettes, which were regarded as virtually a licence to print money. An automatic launderette could be installed in a shop premises because, under the planning laws, it was not regarded as a change of use. These energy intensive, mechanically intensive operations, crammed into small premises, caused serious nuisance and disadvantage to the people forced to live above them. Following on the heels of the automatic launderette had come self-service dry cleaning machines using perchloroethylene or trichloroethylene. The launderettes had been adapted by removing a couple of washers and a dryer, replacing them with two or three dry cleaning machines. The machines were installed by people not necessarily well qualified in ducting skills, as Dr. Aw's slides had graphically illustrated. The standard of work could be appalling. There was a lot of pipework, a lot of joints, many valves and many leaks.

Mr. Barker recalled carrying out an inspection of a fairly new installation where, unbeknown to him, there had been a serious leak over a period of time. He had entered the basement and had been almost overcome by the fumes. All that had been twenty years ago and yet, sadly, the problem remained. Legislation still did not cover the situation - within the whole scheme of environmental problems, it was not regarded as a major cause for concern. There were other priorities for the enforcement agencies to address, yet, as Dr. Monro had demonstrated, it could cause quite serious problems in those who were chemically sensitised. For those who were not so sensitised, even at the very best it was a serious nuisance and disadvantage to which they should not be subjected.

Mr. Barker considered that there was scope for the NSCA to act, by suggesting that the problem could be overcome through a fairly small amendment of the planning laws. Such representations were more than overdue.

DR. J. W. LLEWELLYN (Department of the Environment) said that he had noted from Dr. Aw's presentation that no control group had been studied, yet, as Dr. Munro had pointed out, people could be exposed to perchloroethylene from a variety of sources and through a variety of routes. He asked whether Dr. Aw had any information on the blood perchloroethylene levels in the population as a whole, and any information on the persistence of perchloroethylene - specifically, how rapidly it might be discharged. Finally, he had noticed that passive samplers had been used to measure levels of perchloroethylene in air. These were notoriously variable in their results and he asked whether measurements had been made using just a single passive sampler or whether a number had been used and an average level calculated.

DR. CHING AW said that up to three passive samplers per site had been used and more could have been used if these had been available.

As to the persistence of perchloroethylene in the body, the literature suggested that the biological half-life of perchloroethylene was approximately six days. A single exposure had been known to cause persistence in blood or breath over some hours.

He regarded the points about control groups as very important. In the original protocol, use of a control group was considered. People living above greengrocers shops in the same vicinity were proposed as an appropriate control group. Because of the difficulty of collecting venous blood samples for perchloroethylene in a control group this had to be abandoned. In the exposed group, eight blood samples showed no detectable perchloroethylene. Dr. Aw felt that amongst the general population it would be unusual to find blood samples with measureable perchloroethylene, especially at levels approaching those reported for occupationally-exposed groups.

MR. R. APPLEBY (City of Birmingham) had a point concerning discharges from furnaces serving dry cleaning etc. establishments. According to BS 5440, it was not necessary for the flue to terminate above the ridge of the building roof; the requirement was that, depending upon the pitch of the roof, the flue should terminate a certain distance, perhaps one meter, above the intersection with the roof. Secondly, he had noticed on one of the slides the presence of the ubiquitous "Chinaman's Hat" above the flue. That, of course, would encourage downdraught.

Mr. Appleby also explained that the coin operated dry cleaning machines used a pressurised system to drive the gas up out of the machine and through ducting.

Mr. Appleby said that his department had been carrying out studies in a solicitors' office situated above a dry cleaning establishment. In actual fact, the office was actually above the next building in the terrace. In terms of odour threshold, in that situation people were detecting perchloroethylene at a level of 10 - 15 ppm. A. Miran infra-red gas analyser was in place in the office. On one occasion Mr. Appleby had noticed the smell himself, and, checking the reading on the machine, he saw it move from about 10 to about 15 ppm. Mr. Appleby had also noticed a very pronounced diurnal variation in the level detected.

Although the daily average might be 10 - 20 ppm, hourly averages could be up to to 60 or 70 ppm. A passive sampler picking up a 24 hour average would not record such variations. On a Saturday, when the solicitors' office was shut but the dry cleaning establishment was still operating, hourly values of in excess of 90 ppm had been recorded. In this particular case, the problem was attributed simply to percolation of the chemicals through the fabric of the building. It was very difficult to see how this could be corrected.

DISCUSSION - SESSION 5

Speaker: Dr. Jean Monro

MR. R.A. WALLER (Environmental Consultant) referred to Dr. Monro's comment that between and 10% and 20% of the population were deficient in their ability to detoxify, and that many of her patients were sensitive to pollutants at the ambient levels. Mr. Waller asked how many people could be expected to experience significantly adverse reactions, given a "normal" office.

DR. MONRO said that the first step was decide what were the causes of any illness exhibited. Her own view was that a large body of people suffered from food or chemical sensitivities - this was not a question of allergy but of intolerance due to enzyme deficiency, suffered by normal people in an abnormal situation rather than by abnormal people in a normal situation. She believed that some 30% of the population would be at risk.

MR. WALLER asked whether this would apply without there being anything particularly abnormal in the environment.

DR. MONRO said that in her view the environment was not essentially normal. The difficulty was to obtain a proper standard of comparison. There were very few primitive tribes left on earth but there were Indians living in the Amazon basin in South America (the Wolworoni tribe) who led very fit, active lives until very old age. Although records as to actual DATES OF birth were lacking, some members of the tribe were assumed to be well over 100 years of age and yet they were still shinnying up trees in search of coconuts and running distances of ten miles at a time. They were extremely fit. Moreover, the workers who had studied members of that tribe found no evidence of common western complaints such as rheumatoid arthritis, multiple sclerosis, asthma, eczema. The causes of death amongst the tribe were snake bites and trauma - they simply didn't die of anything else.

Dr. Monro said that one third of people attending a neurological clinic suffered from migraine, one third of people attending a gastro-enterological clinic suffered from irritable bowel symptoms, and both conditions would respond to manipulation of diet and the environment. The load parameter would apply: the load could be lowered in various ways, or the threshold could be raised. The essential thing was to examine the factors underlying the illness and then remedy the environmental or food intake causes.

MR. WALLER said that if the present trend in design and operation of buildings continued, he inferred that 25% of occupants would exhibit some form of adverse reaction.

MR. S. CURWELL (Leeds Polytechnic) asked for further information on the method used by Dr. Monro to monitor the clean environment.

DR. MONRO first set the scene by explaining the background to the Lister Hospital. Lister was of course the surgeon who had discovered that with good antisepsis he could substantially reduce the death rate amongst his patients. He had created an aerosol of phenol, which was sprayed in the operating room using one of the first aerosol machines ever invented. However, it turned out that although he had done the patients a tremendous favour, the operators had suffered. Over twenty years or so most of the people working in the operating theatre had developed a condition known as phenol marasmus, which caused them literally to waste away. They had developed acute food and chemical sensitivities and died of that condition.

The Lister Hospital had since been refurbished, taking into consideration the rules that Lister had tried to lay down but using a huge air filtration system employing bag filters and then hepa filters and activated carbon filters. The air had passed through all those filters before it was released into the wards. Unfortunately, although Dr. Monro had specified that no soft furnishings should be fitted in her own ward, the carpets had been found to contain dieldrin in their backing, so needed to be removed. Otherwise, the soft furnishings were acceptable, being made of cotton and washed by special techniques.

MR. CURWELL asked whether there had been any problems with the air conditioning system in the building, and whether any of the bacteria referred to earlier in the Workshop had been found.

DR. MONRO said that to her knowledge no such bacteria had been found in the building or ventilation/humidification system. However, initially air had been re-circulated in order to conserve heat but that had created too many problems for hypersensitive patients in her ward, so that the air supply had been adjusted there to ensure fresh intake of London air (well filtered).

MR. A. GILBERT (Warrington Borough Council), referring to the point about 10%-20% of the population being hypersensitive to chemicals etc, said that this was of concern to him in relation to emissions from certain works within his own area of Warrington. No doubt other areas had similar chemical works. One works in particular gave rise to a low level of complaint in relation to soapy odours. The small number of people making complaints certainly appeared to be hypersensitive to the emissions. They also had other clinical problems, being prone generally to eye irritations and respiratory tract infections. These people were making regular complaints which posed very practical enforcement difficulties. It was very difficult to control emissions from works on the basis of reactions from an abnormal section of the population. The choice was between enforcing the most rigorous standards to protect that small section of the population or trying to tackle the hypersensitivity itself through individual treatment or encouraging avoidance of the exposure situation.

DR. MONRO agreed that there was a problem. Only in the last year or so had it been possible to measure enzyme systems via the debrisoquin and mucodyne test, giving the patient a pill which would be broken down by a known pathway and then examining the urinary breakdown products of the pill. In that way it was possible to tell whether the sulphoxidation or oxidation mechanism was intact or not. The procedure had been followed for a large control group of the population which apparently had no symptoms; it had been discovered that there was actually a 10% deficit in

oxidation and 20% in sulphoxidation. Thus, a large proportion of the general population would have some deficit in their detoxifying system. Effectively, they had a genetic make up which constituted a time bomb waiting for an environmental overload to trigger it off. It was impossible to predict what type of environmental overload individuals would face. Where people were actually showing symptoms and suffering, they could only be protected by lowering the environmental overload, raising their threshold and feeding them with vitamins to protect them so that their enzyme system, such as it was, would work to maximum efficiency.

MR. GILBERT said that nevertheless there were practical problems in asking a company to invest perhaps millions of pounds in an odour control system in order to protect a very small percentage of the population who were afflicted with a genetic problem.

DR. MONRO pointed out that it was not such a very small percentage.

MR. GILBERT, acknowledging that fact, said that recognition of such clinical problems was still at an early stage and he wondered whether it might be more appropriate to put hypersensitive sufferers in touch with specialists such as Dr. Monro rather than require industry to embark on a massive pollution control expenditure to protect the minority.

DR. MONRO still considered that the proportion of the population affected would warrant legislative action.

DISCUSSION - SESSION SIX
Speakers: Dr. Malcolm Fox, Peter MacDonald Roy A. Waller and Steve Curwell

MR. M. SQUIRRELL (Leeds City Council) observed that it was very difficult to relate odour levels to contaminants - there was little correlation between the gas phase, which gave rise to odour, and some of the particulates which might be present. He agreed that architects needed definitive standards to design ventilation levels in buildings and that Environmental Health Officers also needed definitive standards in order to enforce the initial Health & Safety at Work Act. At present, the only standards were those in Document EH22, which had been based on work carried out in 1936. He considered that the regulations should be revised. As to lead dust and vacuums, Mr. Squirrell recalled that a paper presented to the Stockholm conference on indoor air quality had dealt with the question of re-suspension of hoover dust.

Turning to the presentation by Peter MacDonald, Mr. Squirrell referred to the problem of air by-pass, which had been noted by a number of workers making measurements of the efficiencies of air filtration devices. He wondered whether that problem was recognised by AAF, and whether it was drawn to the attention of the companies using filters. There seemed little point in employing a filter with an efficiency of 99.99% if half the volume of air by-passed the filter.

PETER MACDONALD agreed that this was a real problem. Indeed,if 1% of the air by-passed the filter, then most of its value would be undermined. Careful attention to the installation of the equipment was essential.

MR. R. HANLON (Belfast City Council) was confused by the conflicting statements on humidifiers. Dr. Pickering had declared them to be of little use in the UK situation, whereas Mr. Waller had suggested that humidification should be improved or even maximised. In Dr. Pickering's absence,

he asked for Mr. Waller's comments.

MR. R. WALLER said that he had not been present to hear Dr. Pickering speak, but he understood that Dr. Pickering's research had identified a number of problems deriving from humidifiers. However, these were essentially problems of humidifiers rather than of high humidity. Mr. Waller had simply been suggesting that other problems, eg eye irritation, were more likely to occur if humidity was low than if it was high. In the context of that statement, he was not concerned with the means of supplying humidity, which might indeed create problems unless the system was carefully maintained.

MR. S. CURWELL intervened to say that Dr. Pickering had found that, even in mechanically ventilated situations, provided that the ventilation was right, there appeared to be no reason to supply humidity artificially in order to maintain comfort levels.

DR. D. GREGORY (BSRIA) said that the papers presented during the Workshop had accentuated the lack of an inexpensive method of measuring air change rates in buildings. While such measurements might be affordable in large commercial buildings, there was no economical means available for householders to measure air change rates in their homes. Trying to establish ventilation standards without a means of measuring air change rates that was not astronomically expensive was absurd. It would be like trying to enforce speed limits for cars when the speedometer cost £10,000 - such an instrument might be fitted to a bus but could not be afforded for the average car. One of the messages that might usefully emerge from the Workshop was a call for research agencies to develop a good cheap and reliable method of measuring the rate of air change, that could be used by the householder after he had done draught stripping, for example.

Turning to the paper by Peter MacDonald, Dr. Gregory said that the fibre sizes used in the filters were, in diameter at any rate, about the size of the particles that were of concern and which they were aiming to trap. He wondered if there was any possibility, for example through some abuse of the filter, of the filter material itself breaking up and releasing into the atmosphere fibres/particles of the very size which they were intended to collect.

MR. MACDONALD said that the short and honest answer was, "yes". His company had looked at the attrition rates of various fabric filters. The answer to any possible problem was to run the filters for 4 hours, which should shake out any loose fibres, and the attrition rate thereafter would be very low. Even initially, the quantities of fibres released would be low, but the attrition rate was highest when the filter was new.

MR. W.F. SNOW (Warrington Borough Council) hoped that the Workshop would turn its attention to the problem of emissions from unflued gas cookers and heaters in houses. It seemed to him wrong that there was the question of energy conservation, of draught sealing and need for adequate ventilation rates in houses, without making reference to the fact that cookers were still manufactured without the requirement that they be flued to the outside air, and they were often left running for long periods in poorly ventilated properties.

The other problem he wanted to raise was that of condensation, which was a very real headache for local authorities, particularly with older council housing. The condensation in such properties could be cured, but only at great cost.

Finally, turning to the presentation by Dr. Monro, Mr. Snow wondered how much her patients differed in their sensitivity from a "normal" group of people, such as those present at the Workshop. He thought it likely that most people in the room would be susceptible to at least one substance, but most had presumably not been tested and presumably did not appear to suffer any particular allergy. He wondered whether Dr. Monro's description of "patients" included healthy people, or whether all those she had treated had been ill at the time.

DR. J. MONRO said that all those she had treated had presented with symptoms, but similar symptoms might be present amongst the general population. People did not necessarily make the connection between a food they had

eaten or substance they had been exposed to, and the particular symptoms they were experiencing. Because she had drawn her conclusions from studies of her patients, there was a certain amount of bias, but overall the symptoms were common amongst the general population: asthma, eczema, rhinitis, rheumatoid arthritis, some other auto-immune diseases - multiple sclerosis etc. All those conditions would respond to environmental control, but whether or not this was done depended on how the physicians perceived the complaints. They could treat the condition with steroids etc to relieve the symptoms, or they could look for the cause or causes of the condition.

Dr. Monro entirely agreed that the majority of people in that room would suffer from some sort of symptom. A high number of people suffered from headaches, which had overtaken back pain as a primary cause of loss of work hours. However, unless people experienced these conditions to an extent that it interfered with their lives, they did not necessarily look for causes but simply took a pain killer when needed.

Turning to the point about gas cookers, Dr. Monro said that of the 171 patients she had studied, approximately 30% complained of being unable to tolerate fumes from gas appliances. She believed that this was due partly to the fact that the cookers were not vented but also to the fact that there was inevitably a leak when gas was put on and off, using a pilot light. There would always be a certain leakage of gas, maybe infinitessimal but nevertheless pertinent in the case of people who were chemically sensitised.

MR. WALLER said that he was a member of the general population, who had found himself sensitive in two areas - some ten years earlier he had found that his health improved upon giving up caffeine, and he also suffered from hay asthma. In general conversation, he had found an enormous number of other people who recognised similar symptoms in themselves, but had not realised that it was a problem with a specific cause, thinking it just to be a part of life.

MR. A. CURRAN (British Gas Plc) said that there had been a host of studies into the possible effects on health and the indoor environment of gas cookers. Many of these studies had focused on the incidence of respiratory illness in young children. Indeed, former NSCA meetings had included papers on this subject. British Gas had measured concentrations of combustion products in kitchens where gas cookers were used. Many other organisations had done the same sort of measurements and published the results. As to the health side, British Gas had left such studies to the experts. As he understood it, the results were conflicting. Some studies showed an effect, albeit very, very small, and others did not. Even in those studies which showed some effect, it was very difficult to determine what the causative agent was. The most obvious target was nitrogen dioxide, but it was by no means proven that NO2 was a problem in this context.

Other factors had been considered, particularly the socio-economic groups using gas cookers as opposed to electric cookers, type of housing, etc. The studies by Melia et al had moved on to consider factors such as humidity, examining levels in bedrooms etc.

However, he thought that people in general when cooking in the kitchen responded to increases in temperature, odour or condensation by opening the window. It was an automatic reaction which had a dramatic effect on the ventilation rate in the kitchen and in turn had a very significant effect on any concentration of pollutants. The profile of concentrations of combustion products from gas cooking was unusual - peaky by nature, and very short-lived.

While it was possible to flue a gas cooker, it was expensive and the gas industry regarded it as unnecessary.

MR. CURWELL said that he had discussed the question of condensation with Peter Warren of the BRE, who had given it as his opinion that the use of a standard humidistat in combination with an extract fan (with a humidity reading of a certain level triggering the fan into action) would cure the problem of condensation and ensure good ventilation rates at one and the same time. That was an opinion rather than a research finding, however. Such humidistats, reasonably priced, were already available.

DR. MONRO asked Mr. MacDonald whether the filtration

equipment he described had any bearing on chemical levels in the environment. She realised that they were used to trap particulates but she was also interested in gaseous and other forms of chemicals.

MR. MACDONALD said that the filters trapped particulates and also liquid aerosols as well as solid aerosols. However, the filters he had described were totally ineffective against gaseous molecules. The only cure was to use a carbon filter or scrubber for gaseous pollutants, and those were rather expensive forms of control equipment.

DR. E. HAMPTON (Glasgow City Council) said that people assumed when they bought a car that they would have to have it serviced. However, they did not make the same assumption when they bought a gas cooker and many times when he had been called to investigate a problem, he had found that it was due to lack of maintenance of the appliance. He had measured carbon monoxide levels above the grill of gas cookers at several hundred parts per million, resulting in a background level of 20-30 ppm which could give people headaches. He had also been interested in the presentation by Dr. Fox on CO levels in car parks. He himself had carried out a fatality enquiry in Glasgow in relation to portable gas cookers in a security van. In the case in question, two young men had died from a mixture of carbon monoxide, carbon dioxide and nitrogen dioxide, with levels so high that 20 minutes after switching the grill on, the CO levels had been 500 ppm, ten times higher than the occupational exposure limit. Carbon dioxide had been 15,000 ppm, whereas the background level of carbon dioxide was 400 ppm and the occupational exposure limit was 5,000 ppm. The nitrogen dioxide level had been 6 ppm, whereas the occupational exposure limit was 3 ppm and the background level in a normal city street of 0.035 ppm.

DR. M. F. FOX said that given very restrictive ventilation rates, concentrations of pollutants could rise very rapidly and people had to take precautions accordingly.

On roll on, roll off ferries, for example, pollutant levels could build up appreciably as vehicles were loaded on and if, on reaching port, drivers started their engines before the loading bay doors were open, then concentrations of carbon monoxide could rise rapidly. Concentrations of up to 3,000 ppm CO had been recorded on the car deck of a roll on, roll off ferry. He had been involved in an investigation into the problem, and as a result of that study car deck controllers had been told to instruct drivers not to start their engines before the car ferry's doors were opened. One of the underlying problems behind the tragedy of the "Herald of Free Enterprise" was that it had started its voyage with the loading bay doors open, perhaps in an attempt to clear the car deck of fumes. He believed that the owners of the ferry should have invested more in forced ventilation so that the vessel could have set sail with both the front and rear bay doors closed.

Turning to a comment made earlier by Steve Curwell, Dr. Fox said that he wished to highlight a cross-sensitisation or synergism which might affect some DIY enthusiasts or indeed building operatives. He explained that paint strippers were a mixture of methanol and dichloromethane, or (methylene dichloride). These were both very thin and mobile liquids, to which were added carboxymethyl cellulose, (like "Polycell" paste) to thicken it so that it would stand up on vertical surfaces. Chlorinated hydrocarbons have a narcotic, anaesthetic effect. If people conducted paint stripping in a closed room, applying paint stripper repeatedly to multiple layers of paint, the level of chlorinated hydrocarbon would be quite high and the person doing the paint stripping might feel a bit sleepy. But something not well recognised was that if people followed up their paint stripping activity with alcoholic drink to relax or refresh them, that would produce a dramatically intensified narcotic effect. Indeed, people could actually pass out as a result of taking alcohol on top of inhaling the fumes from paint stripping.

END OF DISCUSSION

CONCLUDING REMARKS
by
The President of the National Society for Clean Air
Councillor L. Poole, BEM, JP

Councillor Poole congratulated all speakers at the Workshop for their first class presentations. They had covered a wide variety of topics. There was food for thought for the National Society for Clean Air, and scope for action. The NSCA was a pressure group but not simply one that declared itself against pollution: it went beyond protest, to promote practical solutions to problems of air pollution, noise and environmental contamination in general. The broad spectrum of NSCA membership, which embraced experts and ordinary people alike, recognised the debt they owed to future generations in shouldering their responsibility to act on the basis of developing knowledge of indoor air pollution and other pressing issues. But the NSCA depended for its strength on a constant intake of new blood and new ideas. The President made an appeal for all delegates attending the Workshop who were not yet members of the NSCA to consider what the Society could do for them, and what they, through their involvement with the NSCA, could do for the environment.

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