POSTNOTE

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UK Indoor Air Quality

It is well established that outdoor air pollution is harmful to human health. However, less attention has been paid to the potential health effects of indoor air pollution. This POSTnote describes sources of indoor air pollution, the evidence for adverse effects on human health and outlines possible policy responses.

Overview

- Indoor air pollutants are potentially important but the extent to which they affect health is not fully known.
- Currently no single government department has ownership of this issue.
- Heating and cooking appliances and environmental tobacco smoke are the most important indoor sources of pollution in UK homes.
- The main health effects are to the lungs and heart.
- Children and those who are already ill are most at risk.
- Future concerns include the potential chronic (long-term) health effects of pollutants at low levels of exposure.

Background

Indoor air pollution is a mixture of

- pollutants generated inside a building from building materials, furniture and furnishings, or by activities such as cooking, heating, smoking and use of paints, varnishes, cleaning products, air fresheners, etc.
- pollutants generated outside a building (by industrial processes, traffic emissions, etc.) that migrate indoors through windows or other means of ventilation.
- natural radon gas that enters buildings from the ground.

Levels of indoor air pollution thus depend on a range of internal and external factors. These include behaviours such as smoking, as well as geographic factors such as whether the home is in a high risk-radon area, or in close proximity to a busy road. Moreover, levels of pollutants may vary from room to room within a home (see Figure 1).

The different types of air pollutants found indoors are outlined in Table 1, and discussed in more detail in the following sections. While gases such as carbon monoxide and radon are known to be harmful to health, evidence on the health impacts of other substances is less clear cut.[1] This is partly due to a lack of monitoring of levels of indoor pollutants and partly to a lack of research on health impacts. In general, children and people with respiratory or cardiovascular illnesses are thought to be at highest risk of health problems from indoor air pollutants.

Table 1 Pollutants, Sources and Health Impacts

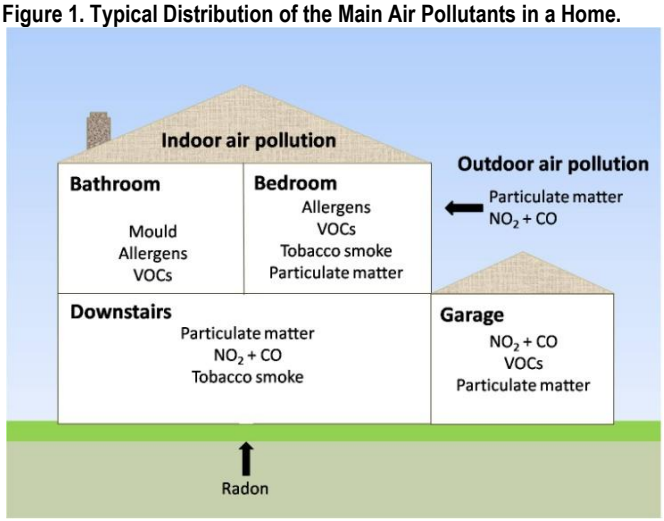
Pollutant	Sources	Health Impacts
nitrogen dioxide (NO_2)	heating and cooking appliances	associated with respiratory symptoms
carbon monoxide (CO)	heating and cooking appliances	lethal at high levels, potential chronic effects at low levels
particulate matter (PM)	cooking and aerosols	reduced lung function and increased risk of heart and respiratory disease
radon	ground gases especially in defined areas	lung cancer
environmental tobacco smoke (ETS)	cigarettes, cigars and pipes	lung cancer, chronic obstructive pulmonary disease, asthma and reduced lung function
allergens	moulds and house dust mites	worsening of symptoms of asthma; causation of wheezing
volatile organic compounds and ozone	cleaning products, paints and printers	respiratory tract irritation, possible effects on asthmatics

Pollutants, Sources and Health Impacts

Particulate Matter (PM)

PM consists of tiny solid or liquid particles found in the air. They are produced by activities such as cleaning and cooking. For instance, stir frying produces a lot of PM including superheated oil particles.

Figure 1. Typical Distribution of the Main Air Pollutants in a Home.



It has long been thought that PM can damage the lungs and cardiovascular system. Deposition of particles in the lung depends on particle size: the smaller particles penetrate deeper and deposit in the air sacs and can cause inflammation. This, in turn, can change the clotting properties of the blood and increase the chances of heart attacks.[2]

Nitrogen Oxides

Oxides of nitrogen found in indoor air include nitrogen dioxide (NO_2), nitrous oxide (N_2O) and nitric oxide (NO). They are formed at high temperatures when fuel is not completely burned, for instance due to a faulty appliance. Possible sources in the home include gas, coal and wood based cooking and heating appliances. Alternatively, NO_2 from vehicle emissions may also enter buildings (Figure 1).

The Committee on the Medical Effects of Air Pollutants (COMEAP) suggests that higher levels of NO_2 indoors is associated with higher levels of respiratory symptoms in children.[3] COMEAP also recommended more research on the possible health implications of NO although this is more relevant to outdoor air quality.

Carbon Monoxide (CO)

CO is a colourless and odourless gas produced (like NO_2) by incomplete combustion, usually from gas cookers or solid fuel boilers. CO is highly toxic to humans and causes around 50 accidental deaths a year in England and Wales. Some are concerned that long-term, low-level exposure to CO could damage the central nervous system, possibly resulting in alterations of behaviour, memory and brain function.

Environmental Tobacco Smoke (ETS)

ETS is the smoke formed when burning a tobacco product, such as a cigarette, cigar or pipe. It is mainly composed of the smoke from the burning end which contains over 4,000 different chemicals, toxic gases and reactive compounds.[4]

People most heavily exposed to ETS are those that smoke, or who live with a smoker. Smoking is the major cause of lung cancer deaths in the UK, directly accounting for 90% of cases.[5] It is estimated that ETS in the home causes around 11,000 deaths every year in the UK from lung cancer, stroke and heart disease.[5] Exposure to ETS can also reduce lung function, trigger asthma attacks, irritate eyes and cause headaches/nausea.[6]

Radon

Radon is a gas produced by the radioactive decay of uranium which is present in soils and rocks in small quantities. High levels can occur almost anywhere but are more prevalent when the ground is particularly porous and/or rich in uranium. Radon decays into radioactive particles such as lead, bismuth and polonium, which can be inhaled and cause lung cancer. [7] The Health Protection Agency's (HPA) Independent Advisory Group on Ionising Radiation estimates that residential radon exposure contributed to about 1,000 (or 3% of total) UK lung cancer deaths in 2009. The great majority of these cases were caused by a combination of radon and ETS exposure in smokers and ex-smokers. Current radon regulations are summarised in Box 3 (Page 4).

Allergens

Allergens are biological particles that cause an allergic response in some people. The main sources of allergens in the home are house dust mite excrement, fungal particles, pet dander and pollen. The levels are elevated in humid, damp houses. Allergens are sensitisers and can trigger rhinitis and exacerbate other respiratory illnesses such as asthma. One in five children in the UK carries an inhaler to relieve the symptoms of asthma and one in four pre-school children suffer with wheezing that is not asthma.

Volatile Organic Compounds (VOCs) and Ozone

VOCs include both natural and synthetic chemicals, e.g. formaldehyde, from a variety of sources such as construction products, cleaning products, air fresheners, paints and electrical goods. Research suggests VOCs can irritate the lungs, particularly in children. VOCs may also react with ozone (an outdoor air pollutant known to cause respiratory inflammation produced indoors by some printers) to produce other toxic compounds.

Regulation and Policy

The EU Air Quality Framework Directive (96/62/EC) and its sister directives define the policy framework for 12 potential air pollutants known to have a harmful effect on human health, including NO_2, carbon monoxide and PM. However this framework is wholly focused on outdoor air quality and does not apply to indoor air. UK bodies involved in regulating air quality (indoors and out) include:

- Department for Communities and Local Government (CLG) which takes the lead on Building Regulations through its Housing Heath and Safety Rating System.
- Department of the Environment, Food and Rural Affairs (Defra) and the devolved assemblies which fund the national UK monitoring network for air pollution outside.
- Department of Health and the Health Protection Agency (HPA), which lead on the health impacts of air pollution.

- Health and Safety Executive, which leads on limiting exposure to harmful levels of air pollutants at work (not covered in the scope of this POSTnote).

Issues

In general, the issue of indoor air pollution has been largely overshadowed by the attention focused on air pollution outdoors related to industrial and transport emissions. As outlined in Box 1, there is a need for more information about levels of exposure to indoor air pollutants, as well as the risks posed by long-term exposure and from new developments such as nanomaterials.

Options for minimising the impacts of indoor air pollution fall into four main categories, discussed in more detail in the following sections:

- co-ordination of regulatory activities;
- buildings and building regulations;
- tackling emissions (both indoors and outdoors);
- improving awareness and changing behaviour.

Box 1. Research

Long- term Population Studies into Health Effects and Pollutants in the Home

Most studies on how pollution affects health are small scale, due to costs. Exceptions include the "ALSPAC" study, which collects genetic and environmental information on over 14,000 families[8] and a European study on the link between indoor radon and 7,000 lung-cancer cases. However, limited information on exposure to air pollution was collected in the first of these studies; a larger, more detailed study is required to determine any long-term health effects. Interactions between indoor chemical and biological pollutants and links with exposure to responses are important research areas.

Risks to the 'Healthy' Individual

Many of the acute health impacts of air pollution occur in people who have underlying disease. The longer-term health impacts on the 'healthy' population are largely unknown. Research suggests there may be chronic health effects for adults, children and the unborn. However, this is a complex issue as exposures to pollutants vary with housing type and condition, location and personal habits.

Nanotoxicology

The Medical Research Council is funding research into the effects of PM on the lung. Experts in the field suggest that further research is needed to establish the effects of PM on other organs and the potential impact on foetuses from both indoor and outdoor sources.

Co-ordination of Regulatory Activities

Much of the focus of regulatory activity is concerned with monitoring and controlling levels of outdoor air pollution sources such as traffic and industry. There is concern that the issue of indoor air quality has less 'coverage' than it did 10 years ago. It has been suggested that there is a need for closer co-ordination of policy in this area between different government agencies, and that one way of achieving this would be through the creation of an overall liaison group.

Buildings and Building Regulations

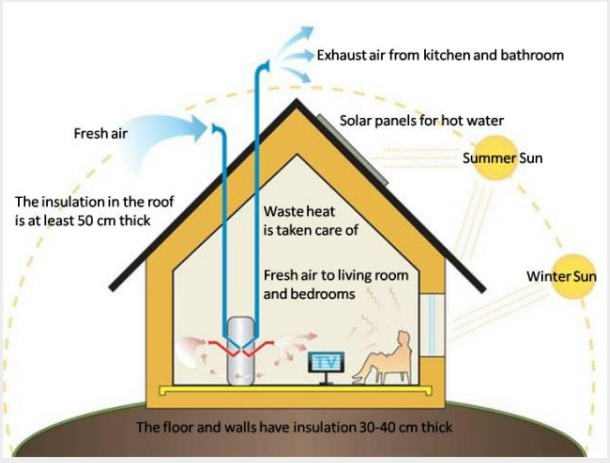
Ventilation and Energy Efficiency

The impact of outdoor air pollution on indoor air quality has been studied by the BRE (formerly the government-funded Building Research Establishment) since the mid-1990s. Its work has identified a trade-off between air-tightness and levels of ventilation; highly airtight buildings are energy efficient but less well ventilated and thus prone to accumulation of air pollutants. The demand for energy efficient buildings is likely to increase, partly in response to growing concerns over climate change. However, BRE is concerned that simply increasing the air-tightness of buildings will reduce ventilation levels and that this may have an adverse impact on indoor air quality.

For instance, several countries changed their building regulations to increase insulation in the 1970s in response to rising energy costs. However, in some Scandinavian countries where homes were constructed using new, less breathable, materials, this led to increasing problems with dampness and mould. This prompted new designs for homes by the late 1980s that combined energy efficiency with high levels of ventilation, as outlined in Box 2.

Box 2. Case Study of Scandinavian Homes: The Passive House

- Designed in Sweden in 1988 and first built in Germany in 1990, passive houses are highly energy efficient homes.
- They have very good levels of insulation and are very airtight. Good indoor air quality is provided by a mechanical ventilation system with highly efficient heat recovery.
- Overall, if correctly maintained, such houses should have low running costs and provide a comfortable living environment.
- There are currently 17,000 passive houses worldwide, with examples across the UK, with the first domestic builds being; Green House, Northern Ireland; Y Foel, Wales; Underhill House, England and Tigh-Na-Cladach, Scotland.



www.passivhuscentrum.se; www.passivhaus.org.uk

UK Building Regulations

UK guidelines for energy efficiency and ventilation are set down in the Approved Documents of the Building Regulations, updated in May 2010. Part L of the Regulations gives guidance on air-tightness, Part F on ventilation, specifying indoor air quality standards for a limited number of substances only, and Part C includes radon. However, the regulations place more emphasis on air-tightness (energy efficiency) than on ventilation. Furthermore, they recommend minimum levels of air flow (ventilation) through a building and assume that outdoor air is 'fresh'. Finally, while the regulations nominally apply both to new buildings

and to work undertaken on existing buildings, in practice they are most likely to be enforced in new developments.

Changing building regulations is one possible way to improve indoor air quality. For instance, the regulations could place greater emphasis on ventilation and the quality of the outdoor air, or set air quality standards for common indoor air pollutants. Local authorities could exercise Part 1 of the Housing Act 2004 to deal with hazards including those relating to indoor air quality.

Box 3. Current Radon Regulation

Building Regulations and Radon

The Building Regulations stipulate that any new buildings or extensions made to existing buildings in areas with the greatest chance of high radon require protective measures to be taken against radon entering the building. This may be changed to include all new builds wherever they may be situated, following advice from the HPA.

The Action Level for Radon

The amount of radon is measured in Becquerel's (a measure of radioactivity) per cubic metre of air (Bq m^{-3}). The average in a UK home is 20 Bq m^{-3}. The Action Level for radon in the UK is 200 Bq m^{-3}. Households exceeding this level are advised by HPA to reduce radon levels in the home (e.g. by using a small void under the floor which is vented using an electric fan to a high level outlet). A WHO survey found that most countries have reference or action levels in the range 200- 400 Bq m^{-3}. The HPA recently announced that it was introducing a 'target level' of 100 Bq m^{-3}, to reflect international guidance from the International Commission for Radiological Protection. This aims to encourage householders to reduce high levels to below the Target Level where possible and seriously to consider reducing levels if they are between 100 and 200 Bq m^{-3}, especially if the household includes smokers or ex-smokers.

Tackling Emissions

Controlling Emissions Outdoors

Reducing emissions of pollutants from outdoor sources such as traffic and industrial processes should result in lower levels of indoor air pollution.[9] While most areas of the UK meet the EU targets for air pollutants, monitoring sites in Central London regularly exceed permitted EU levels for NO_2 and PM. Indeed, the previous government applied for a one year extension to meet EU targets for PM in Greater London. However, in June 2010, the European Commission sent the UK a final written warning about PM levels and could refer the case to the European Court of Justice if the UK fails to comply with the legislation by 2011.

Controlling Emissions Indoors

One way to reduce indoor emissions is by the regular maintenance and servicing of all cooking and heating appliances. The Carbon Monoxide – Be Alarmed campaign is a national campaign launched in 2008 to reduce the number of deaths and illness from CO. It estimated that 15 million UK households do not have their fuel burning appliances serviced regularly. Its two main aims are to:

- encourage regular servicing of fuel burning appliances;
- persuade more householders to fit audible CO alarms.

While regular maintenance can be key to reducing emissions of carbon monoxide, it is not applicable just to fuel-burning appliances. For instance, mechanical heat exchanger and/or ventilation systems also need regular maintenance as a failed motor or blocked filter can result in the accumulation of pollutants indoors.

Awareness and Behaviour

Awareness of Radon

As noted above, awareness campaigns are a means to reduce indoor emissions by informing the public of the dangers associated with some indoor air pollutants, such as CO. The HPA and local authorities conduct awareness campaigns among communities in radon affected areas to encourage householders to monitor radon levels in their homes and to take appropriate action if thresholds levels are exceeded. Campaigns are supported by the government and include free tests and advice sessions for house-holders. The HPA estimates that remedial systems to reduce radon levels generally cost between £500 and £2,000. It recommends that target and action levels, outlined in Box 3, be applied to all schools and places where individual public occupancy exceeds 2,000 hrs per year.

ETS and Smoking

Since the ban on smoking in all enclosed public spaces was introduced in the UK in July 2007, research has shown a 17% reduction in acute coronary syndrome in both smokers and non smokers in Scotland. Of particular concern is the exposure of children to ETS; the Department of Health's Scientific Committee on Tobacco and Health published a review in 2004 noting that ETS is a substantial health hazard and that "no infant, child or adult should be exposed to second-hand smoke". Professional bodies such as the Royal College of Physicians have called for the smoking ban to be extended to include smoking in cars to prevent children being exposed to ETS in a confined environment.

Choice of Products

Another way to limit indoor emissions is to choose products wisely. Flueless gas appliances can be a major source of carbon and nitrogen oxides, particles and water vapour in the home. Other sources of pollutants include furniture, furnishings, paints and DIY products. While some European countries have legislation on the composition and labelling of building materials for VOC emissions, the UK does not currently require such labelling.

Endnotes

1 www.healthy-air.org/28508
2 Pope *et al*, 2006; 56 (6): 709-742 Air and Waste Management Association
3 COMEAP, www.dh.gov.uk/ab/COMEAP/DH_108448
4 www.ash.org.uk/files/documents/ASH_597.pdf
5 info.cancerresearchuk.org/cancerstats/types/lung/index.htm
6 British Lung Foundation and Asthma UK
7 Report of the Independent Advisory Group on Ionising Radiation, HPA
8 Avon Longitudinal Study of Parents And Children, www.bristol.ac.uk/alspac/
9 Ambient Air Quality POSTnote Number 272 November 2006

POST is an office of both Houses of Parliament, charged with providing independent and balanced analysis of policy issues that have a basis in science and technology. POST is grateful to Rebecca Caygill for researching this briefing, to the BBSRC for funding her parliamentary fellowship, and to all contributors and reviewers. For further information on this subject, please contact Dr Peter Border.