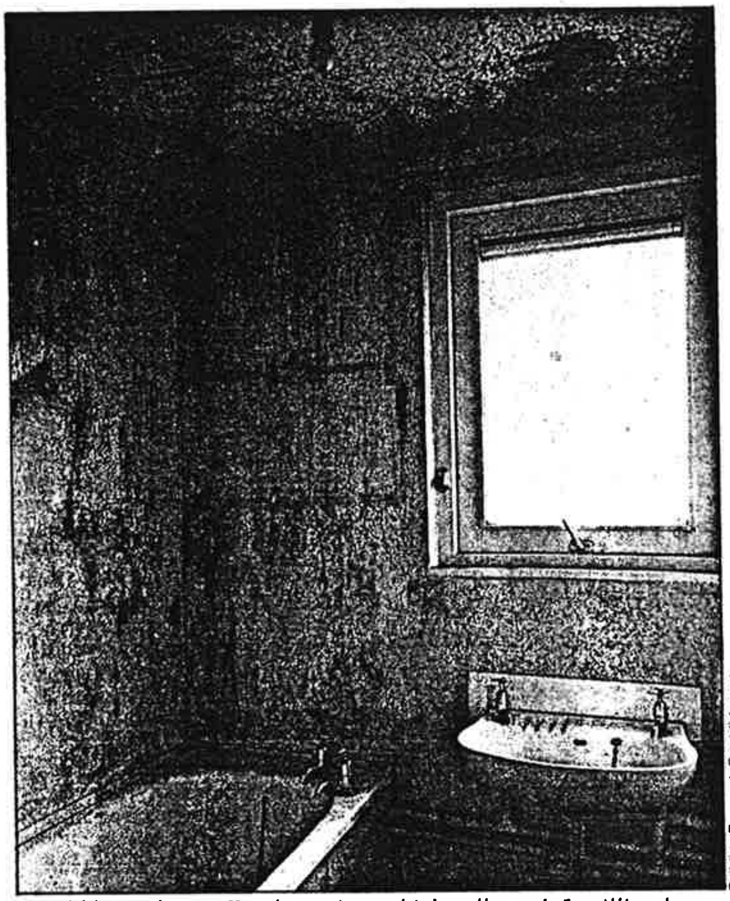
Pollution begins at home

An Englishman's home may be his castle, but it also harbours air pollution that could damage his health. Energy conservation shuts fresh air out of houses and offices, thus increasing the amount of pollution that we live with

Robert Matthews



Building Research Establishment

Mould loves damp. Condensation, which pollutes 1·5 million homes in Britain, is one cause of dampness

TODAY'S draughtproofed and insulated homes certainly conserve energy: they also trap pollutants. Anything that seeps into a house can accumulate in the air and build up to concentrations that can harm the occupants. Already American architects are being threatened with legal action if they fail to tackle the problem adequately. In Britain, the Department of the Environment last month issued guidance to architects on how to design buildings to protect people from indoor air pollution, a risk to health that has caused growing concern over the past five years.

A host of substances can pollute the air indoors. The sources of pollution range from gas cookers to the ground beneath our feet. Indoor air pollution started to cause concern after the energy crisis of the early 1970s. The rising price of oil and other fuels prompted people, urged on by the government, to seal buildings so as not to lose energy. This move to improve insulation in houses compounded an earlier move, brought about, ironically, by concern over *outdoor* air pollution. During the 1950s, the notorious London smog, mainly caused by burning coal, killed hundreds of people. As a result the government introduced "smokeless zones" where it banned coal as a domestic fuel. Homeowners blocked up fireplaces and replaced coal fires with central heating.

Coal fires may be inefficient and dirty, but they do help to reduce air pollution indoors. A fire produces powerful convective forces: hot air rushing up a chimney sucks cold air in through cracks around doors and windows. This constant flow of air carries away pollutants. By sealing fireplaces, we have brought air pollution right into our homes.

Indoor pollutant levels and standards

Pollutant	*Source*	*Typical level*	*Recommendations*
Radon	Soil, Masonry	0·8 millisieverts	5 mSv (NRPB)
Carbon monoxide	Office smoking Gas stoves	15 ppm 5·5 ppm	9 ppm for 8 hr, or 35 ppm for 1 hr, no more than once a year (EPA)
Nitrogen dioxide	Gas cooker	0·16 ppm	0·05 ppm annual mean (EPA)
Dust	Normal activity	53 μg/m³	75 μg/m³ annual geometric mean (EPA)
Asbestos	Asbestos-based materials	5 × 10² fibres/m³	5 × 10⁵ f/m³ for white (occupational) (HSE)
Ozone	Photocopiers, electrostatic air cleaners	0·04 ppm 0·01 ppm	0·12 ppm for 1 hr, no more than once a year (EPA)
Formaldehyde	Chipboard	0·5 ppm	2 ppm (occupational) (HSE)

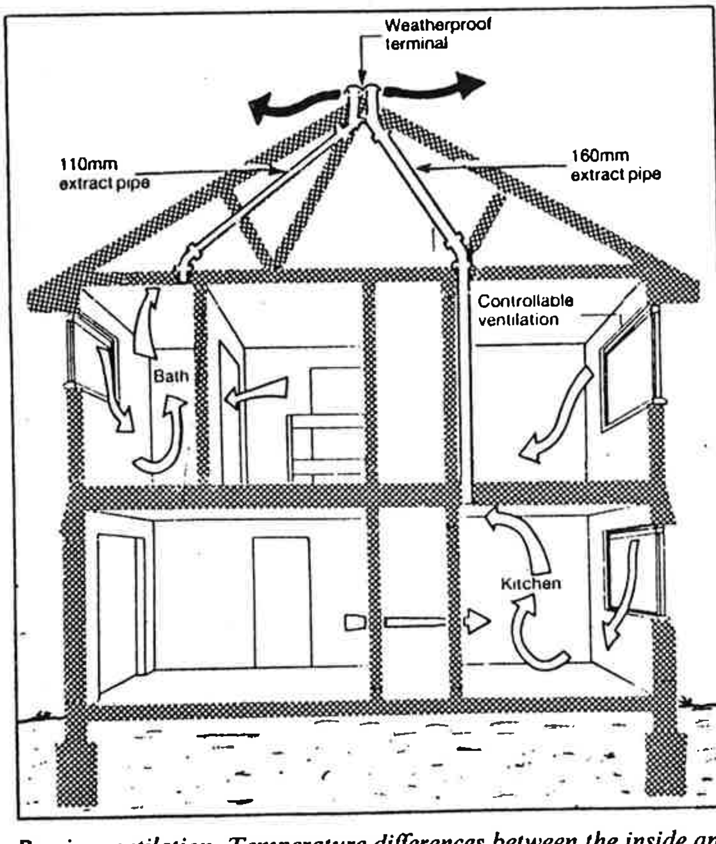
Source of data: NRPB: UK National Radiological Protection Board, July 1983. EPA: US Government Environmental Protection Agency, 1971-9. HSE: UK Health and Safety Executive, August 1984.

The pattern of indoor air pollution is varied, with a number of different sources of pollution, and it is not confined to homes (see Box p 36). In its new guidelines, the government makes it clear that it is as concerned about the damp air trapped indoors as it is about more complex compounds. Certainly, if a "pollutant" is a substance that makes an environment offensive, we have to consider the condensation and the mould, rot and general decay that damp causes. The government's Building Research Establishment considers that condensation is the "pollutant" most in need of attention—a survey by the establishment found that condensation is a serious blight in 1·5 million dwellings in Britain.

Condensation occurs when damp air—with a relative humidity in excess of 70 per cent—remains in a building. Cooking, drying clothes and bathing can easily produce such high humidities. Activities indoors may not be the only culprits—a recent study of condensation in homes in Glasgow implicated the weather outside. Professor Thomas Markus of Strathclyde University found a close correlation between humidity indoors and the humidity outside. Markus and his team believe that the weather may contribute to condensation as much as activities indoors. In this case, simply making a building more leaky in an attempt to disperse damp air will be no answer: warm, moist air from kitchens might be replaced by damp air from outside. A better solution would be to use insulation to minimise the amount of heat lost. With better insulation, occupants could keep the temperature of the walls inside a house above the temperature at which water vapour condenses, the "dew-point", more easily.

Pilkington, the glass company, is working with the Timber Research and Development Association and Laing, the housebuilding company, on a more sophisticated approach to ventilation. Scientists at Pilkington have devised a "passive" approach to combat condensation, that needs neither occupants nor an external source of power to work it. The system is, effectively, a return to ventilation through chimneys. But rather than put large fireplaces in every room, the research team fitted small pipes in the ceilings of the kitchen and bathroom of a well-sealed timber-framed test house. This arrangement means that the greatest extraction force, powered by convection resulting from the temperature difference between indoors and outdoors, occurs in the two biggest sources of condensation, where cooking and bathing take place. These activities create heat as well as moisture, and that heat produces the temperature difference that drives the ventilation process. Pilkington's system has the added advantage of working harder when it is most needed: the more people cook and wash, the greater the temperature difference. The pipes in the two rooms can achieve as many as three air-changes an hour while ventilation in the house as a whole stays relatively modest. Of course, in summer the convective force on which the system depends is considerably weaker because there is a smaller difference between the temperature of the air indoors and outdoors. But in summer the temperature of the interior walls is usually above the dewpoint temperature and there is less risk of condensation. Eliminating damp air also reduces the concentration of other indoor air pollutants, some of which appear to be considerably more harmful to people than condensation.

Perhaps the first indoor pollutant to catch the headlines was formaldehyde. Ironically, the rise of this pollutant also came about partly as a result of the energy crisis of the mid 1970s. Formaldehyde vapour seeps indoors when urea-formaldehyde—a material used to insulate cavity walls in houses—cures. This pungent substance causes eye and nose irritation, as well as headaches and nausea in some susceptible people.

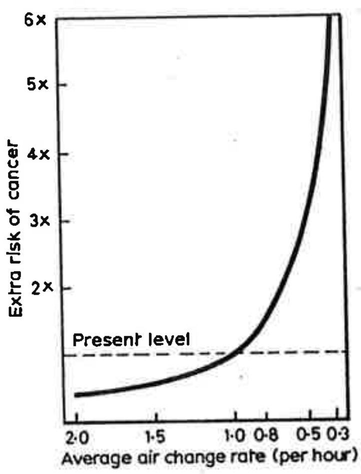


Passive ventilation. Temperature differences between the inside and outside create air currents up the extract pipes

Although the media have focused their attention on cavity insulation as a source of formaldehyde, there are other, more significant, sources of this vapour—for example, glues used in plywood, chipboard and furniture, carpets and combustion. In 1979, a study done by the Lawrence Berkeley National Laboratory in the US showed that the concentration of formaldehyde vapour in the air tripled once furniture was installed in an otherwise empty house.

Media coverage has also caused confusion over asbestos. Prolonged exposure to the amount of asbestos dust found in the textile mills of Rochdale in the 1950s undoubtedly caused—and probably continues to cause—diseases, including cancer. Asbestos in the home presents a very small risk indeed (*New Scientist*, 25 April, p 3). It is also possible to eliminate even this small risk, because building products that contain no asbestos are now available for virtually every application once dominated by this material.

There is a source of air pollution indoors whose effects on health are better documented but perhaps less well recognised: combustion. A number of unfortunate accidents have made clear the danger of breathing fumes produced by faulty gas appliances, but there is evidence that pollution generated by gas appliances operating *normally* may also be harmful, especially to children. Epidemiological studies, such as that of over 8000 children in the US in 1980, hint that gas cookers in the home can increase susceptibility to serious respiratory illness. Gas cookers produce several potentially harmful waste gases. Nitrogen dioxide is probably the most important, although the effects have yet to be proved conclusively. The amount of both nitrogen dioxide and carbon monoxide is much higher in homes with gas cookers. Reducing ventilation in a house has a twofold effect here: not only is there less air to dilute the pollution, the lack of oxygen can change the nature of the chemical reactions that take place in combustion so that the process produces larger quantities of toxic pollutants.



Draughtproofing traps radon, a radioactive gas that can decay into solid polonium in the lungs. Polonium is carcinogenic

Cigarette smoking is the most obvious source of pollution from combustion, and a prodigious one at that. Worse, the smoker is not the only one to suffer. The so-called "passive" smoker breathes in the unfiltered "side-stream" smoke from a cigarette sitting alight in an ashray, which is richer than the filtered and exhaled mainstream smoke in carbon monoxide, ammonia, acrolein, oxides of nitrogen and the carcinogenic nitrosamines and benzo(α)pyrene, to name but a few substances. The end result is that passive smokers considerably increase their risk of developing lung cancer by living with a smoker. A study of over 91 000 Japanese wives who did not smoke indicated that there may be a threefold increase in the risk of contracting lung cancer.

Of all the indoor pollutants so far identified by researchers, the one currently causing most disquiet is the radioactive gas, radon. Radon is dense, invisible and carcinogenic. It is also ubiquitous. Radon comes from the radioactive decay of uranium in the soil. Uranium-238, a common element, decays at a virtually constant rate into a variety of radioactive substances, one of which is radon-222. Radon can seep out of soil and masonry into buildings, where it can accumulate to levels at least 10 times higher than those outside in the open air. Radon-222 itself decays, with a half-life of about 3·8 days,

Offices can be sick places to work in

HOUSES are not the only buildings with pollution problems. Offices present their own set of pollutants and difficulties over ventilation. Failure to solve these problems creates a "sick building".

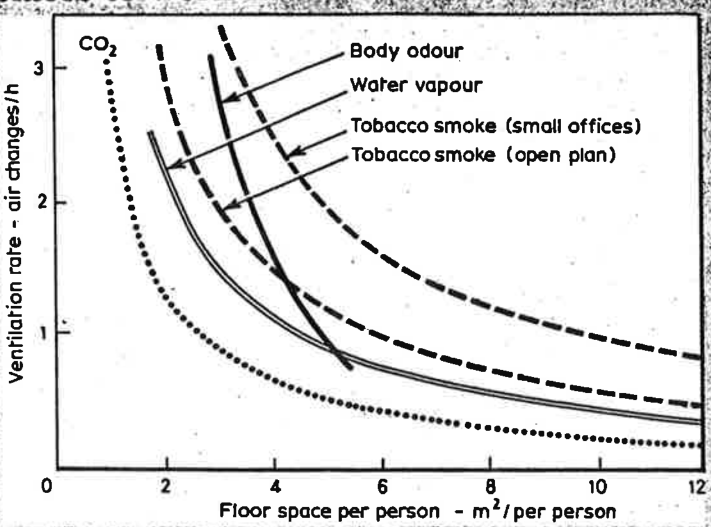
The "sick building syndrome" is not just a case of indoor air pollution on a larger scale. With more sophisticated means of controlling the environment, and the use of air conditioning (particularly in the US), the quality of air in offices is turning out to be more of a problem. The sick building syndrome also seems to affect a significant fraction of the workforce. Earlier this year, the American company Honeywell showed that out of 600 workers, chosen at random, one in five were often or sometimes disturbed by poor air.

The most common manifestation of the sick building syndrome is a feeling of lethargy, eye and nose irritation and breathing difficulties in those who work there. The biggest general complaint made by those in the Honeywell survey was "stuffiness".

Offices, like homes, certainly contain sources of indoor pollutants that could account for some of the symptoms, at least. Formaldehyde from office furniture and carpets, ozone from photocopying machines and other electrical equipment, and organic compounds given off by marker pens and glues are examples. But a more careful consideration of the effects that temperature has on the occupants of a building may also help to overcome much of the trouble.

Several studies have shown that the feeling of "freshness" is intimately linked to ambient temperatures. Experiments carried out by Dr Birger Berg-Munch, of the Technical University of Denmark, revealed that the occupants of a "stuffy" library found that lowering the temperature by less than a degree gave the same increase in freshness as a tenfold increase in ventilation. Reducing the air temperatures from 23°C to 21°C reduced the number of complaints of "stuffiness" by almost two-thirds.

The constancy of temperature provided by air conditioning also appears to be a significant factor in the sick building syndrome. Work by Dr Werner Ranscht-Froemsdorf, of RIB in Stuttgart, suggests that office workers feel happier about the quality of the air if the temperature is lower at the start of the day, increasing to about 21° C as the day wears on.



Air for the workers. The need for office ventilation, as seen by the Building Research Establishment

Using lower temperatures to alleviate some of the problems caused by the sick building syndrome has another attractive feature: it means that stuffiness can be overcome while simultaneously cutting energy consumption.

Other investigations of sick buildings have shown that it is no good simply telling workers that there's enough ventilation: they must be able to feel and control its effect. The engineering company W. S. Atkins and Partners was called in to tackle complaints in an office block built in the early 1970s; it found the usual symptoms, but no pollutants. The company did find, however, that the deliberately draught-free air conditioning was not providing enough air motion to avoid the stuffiness complaint, and the workforce were unhappy about their inability to control their environment.

Thus office designers faced the tricky task of providing enough air movement to overcome stuffiness, without creating a draughty building. The simple answer, it seems (and one being used in such prestigious buildings as the offices of the Shanghai Bank in Hong Kong which opened in July), is to create a controllable environment around everyone's desk using, say air ducts under the floor. □

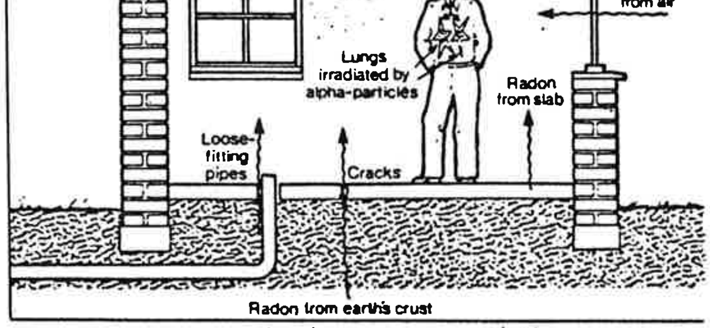
to produce two isotopes of polonium. When inhaled, polonium delivers a dose of penetrating alpha radiation to the lung. It is this that can lead eventually to lung cancer.

Although there were hints of the dangers of radon at the turn of the century, it was not until the late 1970s that anyone made serious attempts to investigate the presence of the gas in homes in Britain. The government's radiation watchdog, the National Radiological Protection Board (NRPB), is currently analysing the results of a nationwide study of radon levels in 2000 homes. The preliminary results are disturbing (*New Scientist*, 26 September, p 19). One in 20 homes in Cornwall exposes its occupants to more radiation than the maximum—25 millisieverts/year—recommended in February last year by the Royal Commission on Environmental Pollution. In some homes the radon level is 10 times higher than this limit, and their occupants may face the same risk of contracting lung cancer because of radon as they face from all other cancers combined.

Other regions where the ground is rich in uranium, such as Devon and the Pennines, also contain homes blighted by radon. West Devon Borough Council has begun to correlate the deaths among its population to areas where the exposure to radon is high in a search for radon-induced cancers.

Radon is not the only radioactive pollutant causing concern: its sister isotope, thoron, is now showing up in levels similar to those of radon. As the half life of thoron is only 55 seconds, less thoron is exuded from the soil, so it is less of a hazard than radon. Even so, the NRPB's studies indicate that thoron may add a substantial and measurable risk to that already posed by radon.

The NRPB believes that around 1000 homes may exceed the level at which the Royal Commission on Environmental Pollution recommends that action should be taken to reduce the hazard, while another 100 000 houses may already exceed the NRPB's own suggested "design limit" of 5 millisieverts. The government has recognised the need for action. Patrick



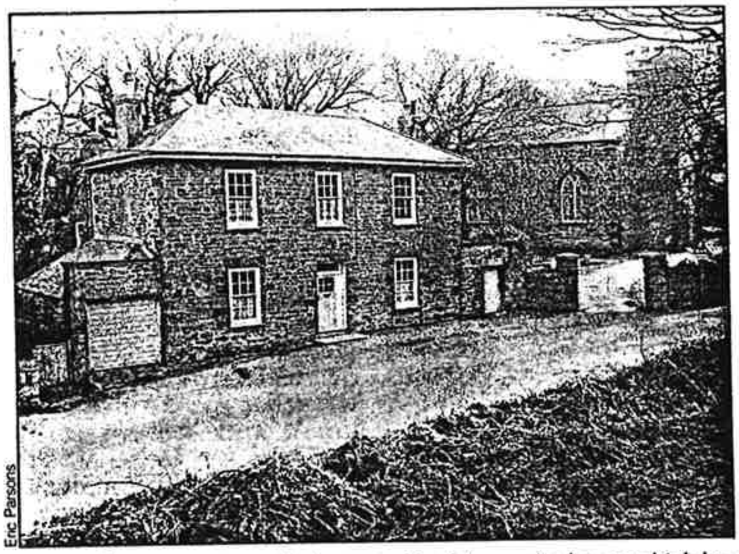
How natural radioactivity enters the home

Jenkin, then the Secretary of State for the Environment, announced in December 1984 that his department would give priority to finding ways of reducing the amount of radon in homes where the radiation level exceeds 25 millisieverts/year. He also said that the government would consider action to prevent new and existing homes becoming unnecessarily hazardous.

One precaution the government could publicise much more widely is the need to avoid excessive draughtproofing in homes. This is important in the treatment of any indoor pollutant—with radon it could be crucial. The NRPB has developed mathematical models that predict that reducing the rate of ventilation by 20 per cent—the sort of reduction produced by installing double glazing and weatherstripping doors—increases by a third the risk of developing cancer.

The NRPB and the Building Research Establishment are working on the problem of radiation in homes. They have a major task on their hands. Even if they use geological maps to locate regions where the soil is rich in uranium, pinpointing homes that are at risk is still difficult. The sheer number of homes in need of treatment or investigation is also a major constraint.

A wide range of measures that would protect people from radon, from opening windows to installing barriers and sub-floor ventilation, have been studied by the NRPB and tried out at a house built from granite near Pool in Cornwall.



Anti-radon measures are being tested in this granite house which has 30 times the normal level of radon

Most of the radon in dwellings seeps up through the floor, so physical barriers can form a first line of defence. The problem is to find the right barrier. Polyethylene sandwiched in a slab of concrete 10 centimetres thick reduced the flow of radon by only one-sixth, but polyamide virtually eliminated the radon. Various other materials have been tried, in an attempt to find alternative measures, but with limited success.

Electrostatic scrubbers—they give particles an electric charge which makes them stick to a filter—can reduce the amount of radon products in the air. But scrubbers increase the levels of another pollutant, ozone, because of their electrical effect on oxygen molecules. Worse, electrostatic scrubbers actually increase the radiation dose to the lung from a given exposure to radon. They do this by altering the proportion of gas molecules that can attach themselves to particles in the air: more of the decay products remain unattached, as the number of particles is reduced, and these can more easily enter the lung to attack cells. Ventilating the voids below a house is particularly effective, however. This measure, perhaps combined with a carefully installed barrier, may be the answer for new homes.

As with radon, there are three ways of dealing with other indoor air pollutants: remove their source, soak them up, or dilute them with fresh air. It seems unlikely, no matter how strong the evidence of danger, that people will give up gas cookers purely on the grounds that they pollute the air indoors. There has to be some other remedy. Chemicals can "scrub" the air of fumes. These work by one or more of three basic processes: absorption, adsorption and porous sorption. Wet-air scrubbers, for example, can remove nitrogen dioxide from gas cookers. Carbon monoxide can be adsorbed onto nickel. Porous sorption, where the pollutant is adsorbed in the porous structure of the scrubbing chemical, seems to work on a wide range of pollutants. Activated carbon (that is, carbon treated with acids to remove hydrocarbons, increasing its ability to retain gases) adsorbs many gases.

Again, the inconvenience and cost of continually renewing such devices as they become saturated, and lose their power to clean the air, means that they are unlikely to find their way into all homes. Electrostatic scrubbers are no better, they not only have to be maintained and cost money to run, but they also increase ozone pollution.

The best way to reduce the level of air pollution indoors seems to be to bring in (relatively) fresh air to dilute pollutants and ensure that there is sufficient oxygen for clean combustion. The government appears to prefer this approach: it has set minimum ventilation requirements, rather than maximum concentrations of specific pollutants. Designers should also find it easier to cope with this approach. However, in an energy-conscious society, simply opening more windows will not do. Our desire to cut energy bills may have put us in the present predicament, but ways of curing the problem of indoor air pollution should not mean a return to yesterday's draughty and inefficient homes. □

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