A deadly gas under the floorboards

Ministers have been warned that some 900 people die in Britain each year from a radioactive gas, radon, bubbling up through their floors. Yet the government last week rejected calls from its scientists for a national plan to make homes safe

Fred Pearce

THEY CALL it the most radioactive loo in the world. It is in a health centre at Chagford on the edge of Dartmoor. Scientists from the National Radiological Protection Board (NRPB) say "if patients spend an hour a day in the toilet they would be exposed to more than the recommended national annual level of radon."

Radon gas bubbles out of the granite rocks beneath the centre and collects indoors. The radioactive loo was discovered during a national survey by the NRPB of radon in homes that is set to be published later this year. The survey found that hundreds of thousands of people in Britain—from Dartmoor to Derbyshire, Kent to the Cairngorms—breathe air in their homes that would not be tolerated inside a nuclear power station.

In the past year, scientists from the NRPB have doubled their estimates of the threat of lung cancer posed by a given amount of radon. And that meant multiplying by 10 the number of houses at risk. After smoking, radon is probably the single biggest cause of lung cancer today killing around 900 people in Britain each year.

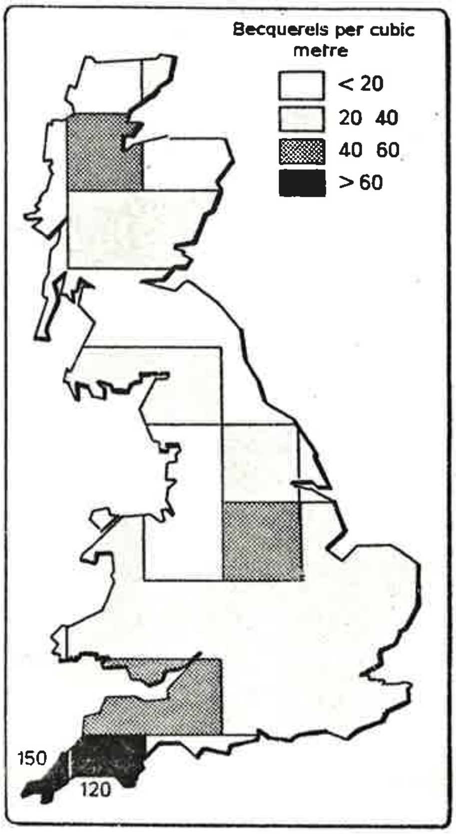
Yet last week, in a statement, the government made it clear that it will not pay for measures to keep radon out of homes. Nor will it pay for the kind of national survey that scientists at the NRPB believes is necessary to discover the 20 000 homes likely to be harbouring lethal concentrations of the gas.

Radon is fast emerging as a major public health hazard throughout Europe and North America. Scientists in the US reported in August that some 20 000 people probably die there from inhaling the gas each year.

In the British survey, several homes recorded radon concentrations more than 50 times the national average of 22 Becquerels per cubic metre. The Chagford loo chalked up readings above 1000 Becquerels. According to the NRPB, these concentrations bring a risk of dying from lung cancer of 5 per cent for anyone living in such a house all their lives. In Devon and Cornwall, a study of 400 houses on igneous rocks found an average 15 times the national average.

Last week, the environment minister, William Waldegrave, accepted a recommendation from the NRPB that a notional "action level" should be set for existing homes where radon concentrations exceed 400 Becquerels. This gives a dose of radioactivity four times the limit set recently by Sir Frank Layfield for nuclear-power workers at Sizewell B.

On the basis of their national survey of 2300 homes, the NRPB's scientists estimate that around 20 000 homes may exceed this level. Some 8000 of these homes are likely to be in Cornwall and



Radon map of Britain. Devon and Cornwall are worst. But few places are radon-free

another 5000 in Devon.

The researchers found readings above the action level in Somerset, the Derbyshire Peak District, Northamptonshire, Clwyd, West Yorkshire, Shropshire, Gloucestershire and Lincolnshire.

The government now intends to alter building regulations in an attempt to ensure that no new houses are built that will harbour radon concentrations above 100 Becquerels. Currently, says the NRPB, some 4000 such houses are built each year. This it regards as a relatively safe level, giving an annual dose of radioactivity to residents of 5 milliSieverts a year, the same as approved for nuclear-power workers. However, according to the NRPB, it still gives a one in 200 chance of giving an occupant lung cancer.

Basic monitoring of houses for radon is easy and costs around £30. The resident is asked to place small pots somewhere safe in the living room and bedroom of the house. The pots contain material that is marked by alpha emissions during the decay of radon and its daughters. These marks can be counted to indicate average radon concentrations.

So far, the NRPB has investigated 3000 houses: 2300 in a national survey and a further 700 in regional surveys in areas with a high risk. Under a contract now being negotiated with the Department of the Environment, the board is likely to investigate another 3000 over the next two years. All will be in the villages in Devon and Cornwall where very high readings above 100 Becquerels have already been found.

This, the NRPB's scientists agree, is bound to leave thousands of homes with high levels of radon undiscovered. The NRPB believes that there are 2000 homes in Britain that will give their occupants doses above 50 milliSieverts (and hence a death risk of more than 1 in 20). So far its surveys have picked up just 24 of these: 19 in Devon and Cornwall, four in Derbyshire and one in Somerset.

The NRPB has not proposed that it survey Derbyshire further. But it will ask the government for money to take a closer look at Somerset, where it so far has only 14 readings—one yielding an exceptionally high result.

The limited survey work now planned for Devon and Cornwall compares with the 40 000 houses that have already been investigated in Sweden and the million homes soon to be surveyed in the US in what a leading researcher there, Anthony Nero, from the Lawrence Livermore Laboratory, calls "the largest environmental search that [the US] has ever undertaken".

Many of the NRPB's staff would clearly like to do more. In 1985, one of the NRPB's top specialists, Mike O'Riordan, told an international conference that a dose of 50 milliSieverts per year "must surely be the level above which no competent and conscientious authority could allow continuous exposure".

"The first duty of competent authorities," he went on, "is to discover where such exposures exist. Some authorities may be reluctant to investigate, rather like the man who fears he has a disease but does not go to the doctor in case it is true." He called radon "a problem of public health for which there should be a public remedy . . . In civilised societies we do limit many kinds of risk and even protect people from themselves."

O'Riordan's colleague, Tony Wrixon, told a meeting of the National Society for Clean Air a year ago that "systematic measurements will be mounted in all likely dwellings" and he called for a programme to detect suspect building sites. None of this is to happen. Large areas of Britain, where the NRPB has identified serious radon problems, are not to be investigated further by the government. And it has no intention of either paying or legislating to control the hazards. Waldegrave said last week that the "responsibility for remedial measures must rest with the houseowner or the landlord." The government was "prepared to consider

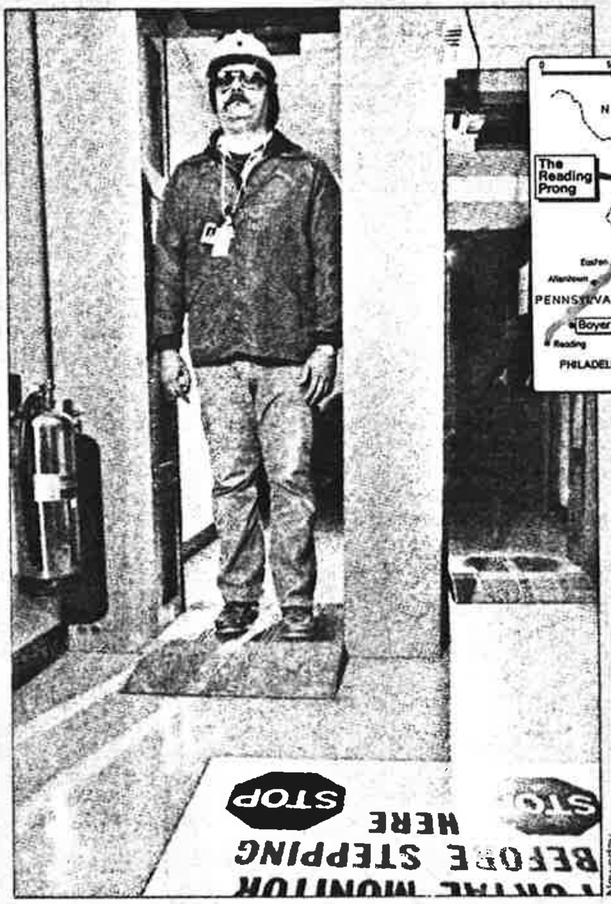
As risky as 135 packs of cigarettes a day

AMERICA woke up late to the perils of radon. It happened on 2 December 1984, when Stanley Watras set off radiation alarms on his way *into* work at the Limerick nuclear power station near Philadelphia. He continued to set off the alarms every morning for a fortnight, until investigators discovered the source of his radioactivity. It was his own home at nearby Boyertown.

Two years later and after thousands of tests in homes all over the US (including 20 000 in Pennsylvania), Watras's house remains the most radioactive found anywhere in the world. "Breathing the air in their house for one day," said researchers later, "was as risky as smoking 135 packs of cigarettes".

It turned out that Watras's home was built on an excavated vein of uranium 10 metres wide. He left his home for six months while the authorities found ways to make it safe.

Last August, the US Environmental Protection Agency reported its preliminary finding that one in eight American homes harbour dangerous amounts of radon. The biggest concentrations were on a geological formation stretching from Pennsylvania through New Jersey and the state of New York called the Reading Prong. High readings were also found widely in homes on the eastern slopes of the Appalachian Mountains, on the phosphate-rich soils of Florida and in western states.



Stanley Watras lights up a nuclear power station. All thanks to the Reading Prong

The agency has set a standard at 150 Becquerels per cubic metre, less than half the British limit of 400 Becquerels. Parts of Pennsylvania and North Dakota had average concentrations of around 300 Becquerels, similar to Cornwall in Britain. The national average was 57.

Reporting in *Science* last November, Anthony Nero from the Lawrence Livermore Laboratory said that in a million homes "annual exposures approximate or exceed those received by underground uranium miners" and "long-term occupants suffer an added lifetime risk of at least 2 per cent". He added that "the occasional houses with concentrations exceeding [2000 or even 4000 Becquerels] cause truly extraordinary risks." Watras's house had a radon concentration of some 100 000 Becquerels. Nero warns that so far "the vast majority of areas at highest risk have not been identified because there has been no effort to do so."

The Pennsylvanian authorities have bitten the radon bullet. But others may fight shy of the consequences. Some state banks now want radon tests to be carried out before they approve mortgages for houses along the Reading Prong. Arthur Socolow from the Pennsylvania Geological Survey told a meeting last May: "The health issues are paramount, but tremendous economic impacts are involved. The value of existing homesteads is at stake, as is the value of undeveloped land. There are a lot of nervous people out there."□

offering financial assistance" only "to the most needy owner occupiers".

Tony James from the NRPB concedes that even in Devon and Cornwall many communities at risk from radon will continue to escape his surveyors. He points out that the government is willing to pay for putting a monitor into the homes of people in high risk areas, if they request it. "We believe that if there is sufficient public interest we will pick up these places as people inquire," says James. "We have limited resources but will build up our knowledge over the next few years. We don't want to panic people."

The main sources of human exposure to natural radioactivity are cosmic rays and the Earth's rocks. Terrestrial sources derive from uranium-238 and thorium. In some places, such as Florida in the US, phosphate rocks mined for agricultural fertilisers harbour high concentrations of uranium. In Britain the most important source is isotopes decaying from uranium on the fringes of granite areas such as Dartmoor and around Land's End.

Radon's immediate precursor is radium-226, which can dissolve in underground water and travel long distances. The importance of radon is that, unlike its predecessors in the decaying chain of uranium isotopes, it is present as a gas that will bubble up out of the ground, making its radioactivity dangerous to anybody breathing it in.

Radon has a half life of 3·8 days and decays to form "daughters". The most important are polonium-218, which has a half-life of three minutes, and polonium-214. They both emit alpha radiation as they decay. These daughters are not gases, but form aerosols and can be breathed into lungs where they form a large part of the radioactive dose.

Keith Ball from the British Geological Survey says that the radon geochemistry of Britain has been well researched, largely on contract to mineral firms prospecting for uranium and other ores. Radon at the surface has proved a good predictor of the presence of uranium deep below ground. Published maps of surface radioactivity formed the basis for the NRPB's choice of areas for its detailed regional surveys of household radon. But Ball believes that unpublished data held by the Survey could be vital in pinpointing communities at special risk.

The amount of radon that escapes from rocks and reaches soils depends on many things. It helps if rocks containing uranium are close to the surface. Even more important is the presence of fissures and faults that act as a pathway for the radon to reach the surface in the few days before it decays. Old mines and adits serve the same role (indeed it was assumed until recently that mines were the only places where high radon levels might be found).

Mines can pose an extra hazard. In Cornwall, for instance, spoil tips from the hundreds of derelict tin mines have been raided by building firms for hardcore and even for aggregate to mix into concrete. According to researchers at the NRPB, "mine spoil from these sources often has elevated uranium concentrations". In a test house the NRPB found that much of the radon seeping through floorboards came from spoil filling the void below the floorboards.

Researchers in Sweden have pinpointed radon gas accumulating in gravels. According to Carole Wilson from the Swedish Radon Commission, gravels or crushed rock can hold large amounts of radon close to the surface. "In such situations, almost unlimited amounts of soil air can be taken into a house without the radon content in the ground under the foundations being significantly lowered."

The commission has concluded that in Sweden, where average radon levels in houses are four times those in Britain, "the critical factor is the volume of soil air that can continuously infiltrate through the foundations".

In the US, Richard Sextro from the Lawrence Livermore Laboratory, says that dangerous radon levels can be found in homes above rocks that do not produce high amounts of radon—provided the soil is permeable. Usually, radon will not percolate more than a metre through soil before decaying to its daughters, which will stay put in the soil. But in coarse gravels and some glacial moraines it can travel up to four metres, says Sextro.

One of the most surprising findings of the research into radon in homes over the past five years is that buildings made of rocks that contain uranium are often relatively safe.

Aberdeen, the "granite city", has been widely assumed to give its residents large doses of radioactivity from building materials. Yet the national survey has found exposure to be less than average. The reasons, says the NRPB's Tony Wrixon, "are not entirely clear." He guesses that a lack of pores or cracks in the Aberdeen granite means that radon created inside the walls of Aberdonian houses cannot escape before decaying.

Swedish researchers report a similar surprise. According to Wilson, when survey work began there in 1979 "it was directed at first towards tracing houses constructed from radioactive aerated concrete (manufactured from uranium-rich, black 'alum' shale) as this was thought to be the main source of indoor radon." But they found that radon from the ground was a far more important source.

The two conditions that allow radon to move from soils into houses are a pressure gradient, and some means of access for the gas. At a house in Pool, Cornwall, the NRPB and the government's Building Research Establishment have been exploring how best to keep the gas out. It is pioneering work with important implications for how Britain responds to the threat posed by radon.

The most obvious method is a leak-proof floor. This is easier said than done. When they installed a concrete floor and sealed cracks and holes round it, the researchers found that radon seeped up through a porous internal wall.

A common assumption is that ventilation keeps radon at bay. The theory is that radon will be blown outside, rather than accumulating in the house. Certainly, the NRPB believes that if every home in Britain were efficiently draught-proofed and double-glazed then average radon concentrations indoors might rise by about a third. But the radon will often be swiftly replaced by new supplies from soil gas. According to Sextro: "A single square inch is usually enough to allow high levels of radon into a house."

Some forms of ventilation will be positively harmful. The NRPB's Cornish house had an open chimney. Wind blowing across the top of the chimney created lowered air pressure inside the chimney and sucked air up the chimney. This is known as the Venturi effect. The chimney was, in effect, acting as a pump to suck radon into the house.

The rate at which radon entered the house was reduced ninefold when fireplaces were blocked off. (Unfortunately this was not a final solution for this house, because it had no damp courses in the walls and relied on the chimney ventilation to keep dampness at bay.)

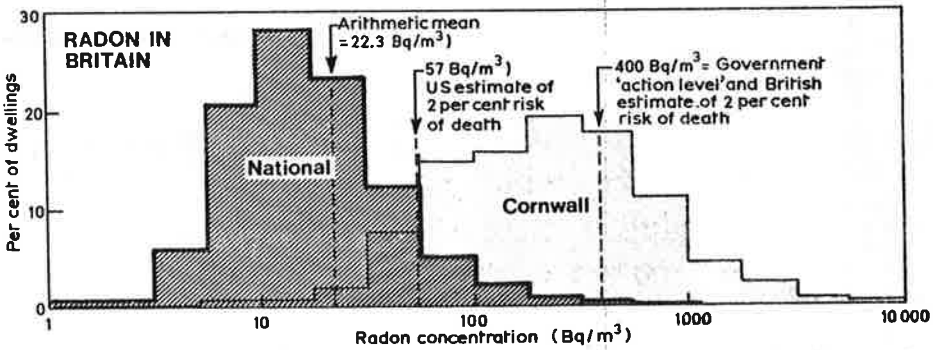
The most effective method of countering radon in existing houses is to eliminate the pressure gradient. In the Cornish house, a fan sucking air out from beneath the floor reduced radon in the house more than any other method. The researchers concluded that "under-floor suction systems are relatively easy to install and cheap to operate. They appear to hold considerable promise."

Sweden's National Institute for Building Research has a variant on this idea, called a "radon reservoir". It aims to suck radon from the soil before it reaches the foundations beneath a house. The institute has sunk a tank, perforated at the bottom, into the back garden of a radon-plagued house. A fan on the top of the tank sets up a pressure gradient in the soil sucking gas into the tank and blowing it out into the air, where it disperses harmlessly. The Swedes say that a single radon reservoir costing £1000 can rid soil covering as much as a hectare of more than 90 per cent of its radon.

Few people, even in Devon and Cornwall, are aware of the extraordinary hazard posed by radon. As Waldegrave pointed out last week: "In Devon and Cornwall, where radon levels tend to be higher than average, the death rate from lung cancer is lower than in many other parts of the country." This is probably because the southwest is a rural area without the history of air pollution that doubles lung cancer rates in most of urban Britain.

According to Tony James at the NRPB: "There is plenty of evidence that uranium miners in Czechoslovakia and Canada have higher rates of lung cancer when exposed to radon levels of the kind found in thousands of British homes." Radon is thought to have caused the high rates of lung cancer among both tin miners in Cornwall and haematite miners in Cumbria.

The first epidemiological data from homes in Norway is also beginning to emerge. James will help with investigating this further. He also hopes soon to begin work for the Department of Health and Social Security looking at health patterns in southwest England.



The epidemiology is backed up with investigations of what happens to radon and its "daughters" inside human lungs. James sits on a UN committee that is taking this route to assessing the risks of radon. In recent months, he has had to persuade his bosses at the NRPB to rewrite their standard tables that convert the concentration of radon in the air into a dose of radiation to the lung. In a report three years ago, they said 57 Becquerels of radon per cubic metre of air was necessary to create a dose of one milliSievert. Now they estimate 20 Becquerels.

A prime reason has been the discovery that radon daughters will irradiate a wider range of cells inside the lung, and thus have the potential to cause more different lung cancers. It used to be thought, says James, that basal cells alone were sensitive. Now he is sure that secretory cells are vulnerable too. James says it is also becoming clear that there are more radon daughters at large in the lungs of people breathing radon. This brings a correspondingly greater radiation dose. He told a meeting of the American Chemical Society last April that these two reassessments meant that estimates of radiation doses for a given amount of radon should be trebled, though he has since moderated this to a doubling.

Even so, the NRPB has had to report to ministers that it has doubled the number of people that it thinks die from radon poisoning. The figures remain educated guesses and authorities in Sweden and the US both make higher estimates of the likely death toll in Britain.

The US says 150 Becquerels per cubic metre over a year gives a dose of 20 milliSieverts. (Britain says it requires 400 Becquerels.) The US says 20 milliSieverts per year gives a lifetime risk of death from lung cancer of 6 per cent. (Britain says it is 2 per cent.) The NRPB has told ministers that between 800 and 900 people probably die from the effects of radon each year in Britain. But if the board had adopted the conversion figures used by the Environmental Protection Agency in the US, then it would predict a death toll of almost 7000.

It is all a matter of how you look at it. As staff from the NRPB said in a note to the Royal Commission on Environmental Pollution three years ago: "The magnitude of the problem is . . . a matter of definition, and no sensible authority would wish to create a problem that could not be solved."

That is something to ponder during draughty mornings on that health centre toilet on the edge of Dartmoor. □