The Earth in our hands

- how geoscientists serve and protect the public

5 RADON

About these briefings

The Earth is a dynamic planet. It is active and productive, offering humanity enormous opportunities. However, living on it also presents us with many dangers; some of our own making.

In our interaction with the Earth, geoscientists are in the front line. They seek and find the raw materials we use for agriculture, roads, buildings, energy, water supply and all the industries that provide wealth and health.

Geoscientists help society understand natural hazards and mitigate their effects. Such dangers include floods, landslips, volcanic eruptions and earthquakes. Geoscientists also help to minimise hazards we have created (or made worse) by our activities. These include subsidence, and the disposal of waste.

With their unique understanding of the immensely long time spans over which Earth processes operate, geoscientists help communities world-wide to learn how to use the planet's resources safely, wisely, and sustainably.

This series of information sheets is dedicated to bringing this role to public attention.

Further information and useful contacts

Web sites

http://www.nrpb.org.uk/radon the National Radiation Protection Board website gives up-to-date information on radon in a question and answer format, lists of publications, maps, useful links, radon measurement services and advice. Free radon information packs and local contact numbers for England, Wales, Scotland and Northern Ireland can be obtained by calling 0800 614529 or 01235 822622 or by post from NRPB, Chilton, Didcot, Oxon OX11 0RQ.

http://www.hse.gov.uk Health and Safety Executive offers guidance and have responsibility for health and safety in workplaces.

http://www.defra.gov.uk The Department of the Environment, Food and Rural Affairs manages the Government radon programme. Free guides to householders and purchasers are available via the Web. For DEFRA free literature, call 0870 1226236.

http://bre.co.uk/radon The Building Research Establishment has information, maps and leaflets as well as a radon advice telephone helpline 01923 664707 or writing to Radon advice, Building Research Establishment Ltd, Garston, Watford WD2 7JR.

http://www.bgs.ac.uk/radon Information on the geology associated with radon, maps of radon risk potential based on geology, and Site Report service to provide geological assessment in support of building regulations.

http://www.radon.com US Radon Information Centre. http://sedwww.cr.usgs.gov:8080/radon/georadon.html US Geological Survey site with information on the geology of radon and useful links.

http://www.parliament.uk/post Parliamentary Office of Science and Technology (POST) makes information available on the web on a number of scientific issues including radon.

Printed material

DEFRA, HSE, BSE and NRPB publish leaflets on radon at home or in the workplace: e.g. DEFRA's *Radon: a guide to reducing levels in your home and Good Practice Guide*, NRPB's *Health Risks from Radon.*

Reducing radon risks in the home, Postnote no. 158, produced by the Parliamentary Office of Science and Technology, is available via their Web site (see above).

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Published by:
The Geological Society of London
Burlington House
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LONDON W1J 0BG
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Series Editor: Ted Nield
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The Geological Society gratefully acknowledges the assistance of the following scientists, who (in a personal capacity as Fellows of the Society) read and commented on earlier drafts of this briefing.

The Geological Society gratefully acknowledges the assistance of its External Relations Committee (Chair, Dr Hazel Rymer) and the following scientists, who (in a personal capacity) read and commented on earlier drafts of this briefing.

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July 2001

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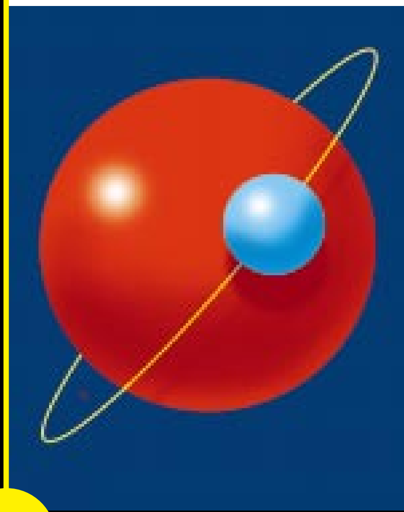

5 RADON

Introduction

Since its discovery radon has found many uses - one of the first as a supposed therapeutic aid. Many people believed that inhaling radon had beneficial effects. Some towns (like Hot Springs, Arkansas, USA) attracted many tourists on the strength of the radon in its thermal waters. As more has become known about radon, so the potential uses of it in geological and environmental applications have grown.

Radon has been used to:

- Monitor atmospheric mixing
- Investigate monsoon circulation patterns
- Predict volcanic eruptions and earthquakes
- Map geological faults and in geochemical exploration

Why is radon a problem?

Radon is an inert gas and is not poisonous. However it is a problem because:

- it is radioactive
- it cannot be seen, heard or felt
- it is all around us

Radon is radioactive and emits high energy alpha particles with relatively short half-lives. These, when ingested, can damage tissues and induce cancers. This means that where radon concentrations are high there is a higher radiation exposure risk. Radon and its decay products account for about half the total average natural background radiation received by the UK population each year (Fig. 1).

Radiation levels are generally low in most parts of the UK (well within the safety limits set by the International Committee on Radiological Protection). However, where its concentrations are high, radon can pose a potential radiation hazard.

Radon and its products are harmful to health. Radon is the second most significant cause of lung cancer (after smoking). The National Radiological Protection Board (NRPB) estimates that between 2000 and 3000 people in the UK die from radon-induced lung cancer each year. Breathing it in causes damage to the delicate cells lining the lungs' passageways and increases the risk of cancer developing.

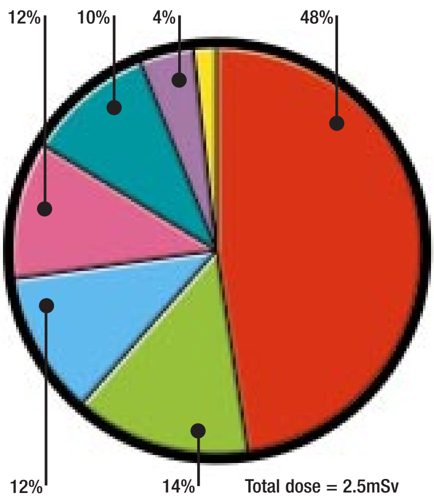

Fig 1: Sources of radiation in the environment

What is radon?

Radon (Rn), a naturally occurring element (no. 86), is a colourless, odourless, invisible gas. It is naturally radioactive and arises as a by-product of the radioactive decay of two other natural radioactive elements, uranium and thorium. Radioactive elements emit radiation when their nuclei undergo a change ('decay') and give off a ray or a particle (energy).

The abundance of radon in air is measured in Becquerels per cubic metre (Bqm^{-3}). One Becquerel (Bq) represents one radioactive disintegration (a nucleus giving off a ray or particle) per second.

Radioactive elements can give off different kinds of particles of differing masses. This results in the radioactive decay products' also having different atomic weights. These forms of the same element are called isotopes, and they may have different stabilities - some decaying very quickly, others slowly. The rate of decay is measured in terms of a "half-life", which is the time required for the quantity of an isotope to fall to half its original amount by disintegration. Half-lives range from a fraction of a second to millions of years. ^{222}Rn has a half-life of 3.8 days.

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Where is radon found?

Radon is found in:

- rock, soil and water
- the buildings we live in, and underground in caves, mines and tunnels
- the air we breathe

Rock, soil and water

The uranium content of a soil will frequently be related to that of the uranium-bearing rock from which it is derived. Rocks that may have higher than average uranium content include some:

- acid igneous rocks, such as granites and some volcanic rocks (e.g. parts of Scotland and Cornwall)
- rocks intruded by acid igneous rocks (e.g. Cornwall)
- dark, organic-rich shales
- limestones and other sedimentary rocks containing phosphate minerals (e.g. phosphate in the Northampton Sand Ironstone)
- rocks derived from those mentioned above by changes in heat and pressure (metamorphic rocks)

The water content of the rock is also significant. Radon diffuses more slowly through water than air. Because of this, rocks or soils with high moisture content impede the diffusion of radon enough for it to decay to harmless levels. In water-saturated rocks or soils, radon generally moves only a few centimetres before most of it has decayed. In areas where the rocks or soils are dry, radon may move more than two metres before most of it has decayed.

Because the half-life of even the longest-lived isotope of radon is short, most of it is radioactively “dead” after about eight half-lives (c. one month), and it is no longer a hazard. The reason that radon remains a problem is that its transport is not governed by simple diffusion. The migration of the carrier medium (air/water, including groundwater) will determine the degree of radon transport. Such fluids may move large distances.

Buildings

Radon can travel through cracks and crevices in the foundations of buildings and into the basement areas and lower floors, contaminating the air in working and living spaces. Radon may also enter buildings via groundwater in wells and from tap water.

There is no atmospheric source for radon. Like all fluids, radon gas moves through rocks and soil and because of pressure differences and differences in gas concentration. Radon will move from regions of higher concentration (from soil and rock where it is formed) to where concentration is lower.

The higher the radon level in underlying rocks and soil, the higher the possible level in buildings can be. Radon moves rapidly through rocks and soils that, for whatever reason, are permeable (have many connecting pores). This is why it moves well through sand and gravel, but more slowly through clay.

Radon entering poorly ventilated buildings and underground areas such as caves and mines may reach potentially dangerous concentrations. The build-up of radon indoors is affected by the building materials used and the method of construction. Both granite and concrete can emit small amounts of radon. Although rarely perceived as a health hazard in the UK, the radium content and radon exhalation rates of concrete and bricks used in Hong Kong have been found to be higher that those in some other countries.

Air

Usually, radon released from uranium-brearing rocks and soil is quickly diluted in the atmosphere and dispersed by the wind. Concentrations in outdoor air are usually very low and pose no health hazard.

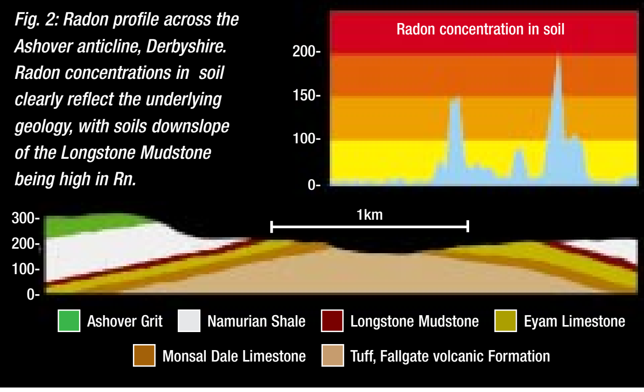

Fig. 2: Radon profile across the Ashover anticline, Derbyshire. Radon concentrations in soil clearly reflect the underlying geology, with soils downslope of the Longstone Mudstone being high in Rn.

Measuring radon - assessing risk

Radon levels in air (indoors and outdoors, caves and mines); soil and ground water vary with:

- underlying geology (rock type)
- structure of the soil (porosity and permeability)
- weather conditions
- ventilation. (Draught-proofing in modern houses traps radon, whereas it disperses more easily from older buildings.)

Since the late 1980s when the problem was first recognised, radon build-up in homes has become a significant public health issue. Some countries, including the UK, test for radon gas in homes to assess risk. Average radon concentrations in the UK and worldwide are 20 and 42 Bqm^{-3}, respectively.

The main risk comes from breathing in the gas. Although high concentrations of radon in groundwater may contribute to human exposure through drinking, the radiation dose from breathing in the radon released from the water is usually more important.

The two main methods used to test for radon gas and its products are “passive” and “active” respectively.

Passive

A device is left for a specific period (usually four days to a week, but sometimes several months) to collect data and is then sent for analysis. Devices of this type include:

- activated charcoal test kits that collect radon and/or its decay products
- small strips of special plastic that record “hits” by radon’s decay products
- plastic discs with an electrostatic charge that attract radon’s decay products.

Active

Continuous radon monitors (CRM) measure radiation levels continuously over a shorter period (c. two days). This method is used mainly by professional radon inspectors.

Advice on radon testing is available from the National Radiological Protection Board (NRPB). See below for more information.

Radon in the UK - examples

It has been estimated that 100,000 people have higher than average concentrations of radon in their homes. Most live in England. More than half of the total live in the following English counties, plus Scotland:

- Cornwall
- Northamptonshire
- Derbyshire

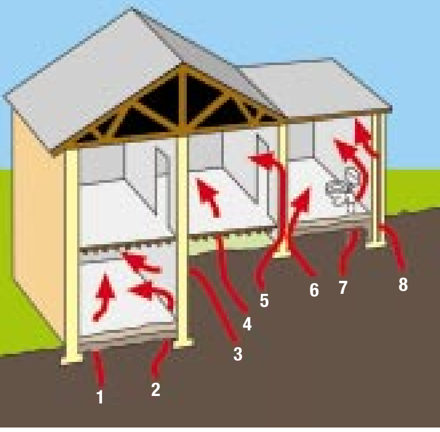

Fig. 3: How radon enters the home. Redrawn from Environment Department leaflet.

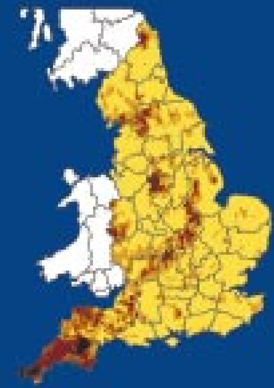

Fig. 4: Estimated proportion of homes exceeding the Action Level in England

What has been done?

Action Levels and Radon Affected Areas

In the home, where people spend most of their lives, the average radon level is 20 Bqm^{-3}. This figure was arrived at after a UK-wide survey by the NRPB of nearly 350,000 homes. These data identified several areas with abnormally high radon levels. This led the NRPB formally to recommend an "Action Level" of 200 Bqm^{-3} for deciding when to take action to reduce concentrations. This has been accepted by the UK Government.

The NRPB also recommended the designation of "Radon Affected Areas" (any area where there is more than 1% probability that a house will be above the action level).

- Cornwall and Devon were declared Radon Affected Areas in 1990
- Northamptonshire and parts of Derbyshire and Somerset in 1992
- parts of Scotland and Northern Ireland in 1993.

In the US, the US Environmental Protection Association (EPA) uses different units of measurement, but has established an Action Level of 4 picoCuries per litre of air, which equals 148 Bqm^{-3}.

Reducing radon risk

There are many ways to reduce radon risk. Most are cheap and simple.

Ventilate

- open windows
- install air bricks in walls just above ground level
- fit an air pump (to pump the gas out)

Reduce access

- seal cracks and fissures in floors and foundations
- pressurise building by blowing air into the house (usually from the attic) to exclude soil air

Divert

- install a sump beneath a building to collect gases, which can then be pumped away

In 1994, NRPB estimated that about 100,000 dwellings in the UK had radon concentrations above the Action Level (95% of which were in England, mainly in Devon and Cornwall).

Radon entering poorly ventilated buildings and underground areas such as caves and mines may reach potentially dangerous concentrations.

The role of geoscientists

Geoscientists have provided their understanding of rock types, their radon potential and the associated hazard. Geoscientists evaluate the radon potential of an area and show this information on maps. They prepare combinations of data, which may also be used by others, from:

- geological maps
- soil surveys
- stream surveys (radon levels in streams and surface waters and its bearing on uranium distribution, fault and fracture systems and human health)
- air surveys (indoor radon data)
- radioactivity maps

Geological maps

Geological maps are used to show rock types against a topographic base map. Areas that have rock types associated with higher than average levels of uranium (and therefore radon) such as some granites can be clearly seen.

Soil and air surveys

Devices placed in the soil, outside or inside buildings, measure radon quantities and conditions (e.g. water content, cracks and fissures in foundations, weather) that may affect the dispersal or build up of radon.

Radioactivity maps

Levels of background radiation from all sources can be plotted on radioactivity maps for example, linked with their Environmental Radioactivity project, the British Geological Survey (BGS) is mapping potential exposure to radon at 1:50,000 scale under DEFRA projects and GeoHazarD.

Site reports

The British Geological Survey (BGS) Radon Protective Measures Geographical Information System (RPM-GIS) provides site reports and geological maps of radon-potential. RPM Site Reports include a geological assessment, which combines data on the underlying geology of an area with radon measurements provided by the National Radiological Protection Board (NRPB). This information is of particular use to developers and for building control.

The search area for a site is increased by a buffer zone of 50 metres in areas with 1:50,000 scale data and 500 metres in areas with 1:250,000 scale. The advisory report indicates the level of protection required within the buffered search area. The advisory reports:

- identify areas for which rigorous building standards for new buildings are required to mitigate radon hazard and to help determine the level of radon protection required in new dwellings
- identify areas where there is a high probability that buildings will be affected by radon (for the cost-effective targeting of radon monitoring in existing dwellings and workplaces).