

Naturally occurring Radon

Overview

- Radon (^{222}Rn) is a natural radioactive gas that occurs in rocks and soils and can only be detected with special equipment.
- It can accumulate in buildings and provides about 50% of the total radiation dose to the average person in the UK (Watson et al., 2005). It is a major cause of lung cancer. Therefore, early detection is essential.
- The British Geological Survey and the Health Protection Agency have produced a series of maps showing Radon Affected Areas based on underlying geology and indoor radon measurements, which help to identify Radon Affected properties.
- Many factors affect how much radon accumulates in buildings. Remedial work can be undertaken to reduce its passage into homes and workplaces and new properties can be built with radon preventative measures.

Radon decays to form radioactive particles that can enter the body by inhalation. Inhalation of these short-lived decay products of radon has been linked to an increase in the risk of developing lung cancer.

Breathing radon indoors is the second largest cause of lung cancer deaths after smoking (HPA 2009). Radon concentrations in outdoor air in the UK are generally low, on average 4 Bq m^{-3} (becquerels per cubic metre) whilst radon in indoor air in UK dwellings ranges from less than 10 Bq m^{-3} to over $17\,000 \text{ Bq m}^{-3}$ (Rees et al., 2011) with a population-weighted average of 20 Bq m^{-3} .

How does the hazard occur?

Radon is produced by the radioactive decay of radium (^{226}Ra), which in turn is derived from the radioactive decay of uranium-238 (^{238}U).

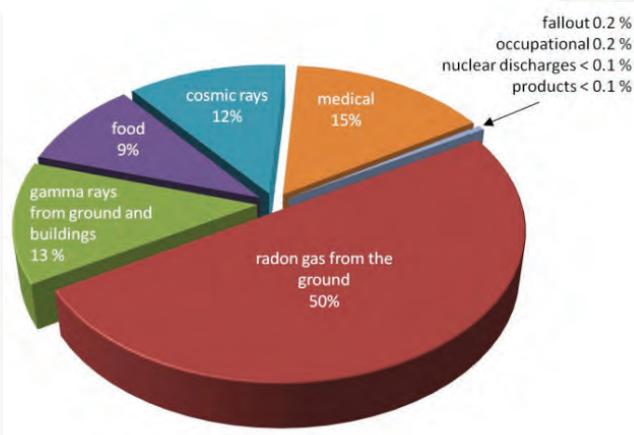
Uranium is found in small quantities in all soils and rocks, although the amount varies from place to place.

How do we become exposed to radon?

Most of the radon atoms formed from the decay of radium remain in the mineral grains. In soils, normally 20–40% (in clays up to 70%) of the newly generated radon atoms are released to the pore space where they are mixed in with the gas (soil air) or water that fill the pores. From the pore space, radon can be transported by diffusion or by flow in carrier fluids such as soil air or water. The rate of release of radon from rocks and soils is largely controlled by their uranium and radium concentrations, grain size, and by the types of minerals in which the uranium occurs.

The most important factors controlling the migration and accumulation of radon in buildings include:

- Characteristics of the bedrock and soils that affect fluid transport, including porosity and permeability;



Proportion of the average annual radiation dose to the UK population (Watson et al., 2005).

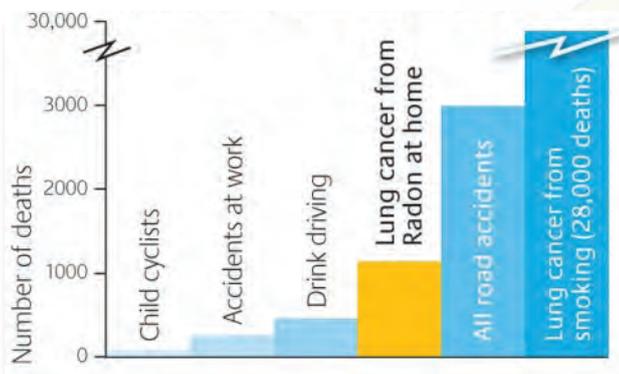
- the construction of the building and its use which includes the level of ventilation and heating; and
- environmental factors such as temperature (increased heating in buildings during the colder months causes a chimney effect which draws soil gasses including radon into the property), plus wind speed and direction which can increase the chimney effect

Radon-containing soil air can be drawn into buildings through gaps and cracks in solid floors, walls and service pipes below construction level; through the voids in suspended floors and crawl spaces, and via small cracks or pores in hollow-block walls or wall cavities.

What are the consequences of exposure to radon?

A study of lung cancer deaths from indoor radon gas was carried out for a Health Protection Agency (HPA) report, *Radon and Public Health*, published in 2009. This estimated that in the UK:

- 1100 lung cancer deaths were caused by radon, representing 3.3% of total lung cancer deaths (34 000)
- The dose-response relationship appears linear, in that the greater the concentration of indoor radon, the greater the risk of developing lung cancer. Also, there is no evidence of any threshold below which there is no risk



Radon deaths compared to other causes of premature deaths per year in the UK. Image © Health Protection Agency.

- Of the 3.3% of lung cancer deaths attributable to radon exposure, only 0.5% were due to radon acting alone: the remaining 2.8% were caused by a combination of radon and smoking, with nearly half the deaths likely to occur in people who had already given up smoking

The HPA research also highlighted that the vast majority of radon-induced lung cancer deaths occur in areas that are not currently designated as 'Radon Affected Areas' (areas in which over 1% of homes are estimated to exceed 200 Bq m⁻³, the UK radon Action Level). The overwhelming majority of the population live outside such areas, and around 95% of radon-attributable deaths are estimated to occur with residential concentrations below 200 Bq m⁻³, and 70% at concentrations of less than 50 Bq m⁻³.

What is the cost to the UK economy?

Estimation of the economic cost of radon-induced lung cancers is difficult. Using the Quality Adjusted Life Years approach (Gray et al., 2009), the total estimated cost of radon-induced lung cancers is £347 million per year.

Susceptible locations

Geology associated with the highest levels of naturally occurring radon are: granites in SW England, the Grampian and Helmsdale areas of Scotland and the Mourne Mountains in Northern Ireland, Carboniferous limestones throughout the UK and some Carboniferous shales in Northern England, sedimentary ironstone formations in the English Midlands (Jurassic Northampton Sand and Marlstone Rock Formations), (some Ordovician and Silurian mudstones, siltstones and greywackes in Wales, Northern Ireland and the southern uplands of Scotland, Middle Old Red Sandstone of NE Scotland and Neoproterozoic psammites, semipelites and meta-limestones in the western sector of Northern Ireland (Appleton and Ball, 1995; Appleton and Miles, 2005; Scheib et al., 2009; Appleton et al., 2011).

Digital geological data compiled by the British Geological Survey (BGS) and measurements of radon levels in homes have been used to produce radon

potential maps showing areas within the UK where there is an elevated risk of high levels in homes. (Miles & Appleton, 2005). National-scale radon potential mapping is carried out by the BGS-HPA approximately every 5 to 10 years, dependent on the numbers of new HPA indoor radon measurements and advances and amendments to the BGS digital geological data.

Scientific detail

How is the hazard characterised?

An Action Level (AL) for radon in homes of 200 Bq m^{-3} has been established in the UK. The Health Protection Agency (HPA) has recommended that parts of the UK with 1% probability or more of homes being at or above the Action Level should be designated as Radon Affected Areas. In 2010, HPA guidance on radon gas concentrations introduced a new 'target level' of 100 Bq m^{-3} above which remediation work should be seriously considered especially by high risk groups such as smokers and ex smokers.

Monitoring and measurement

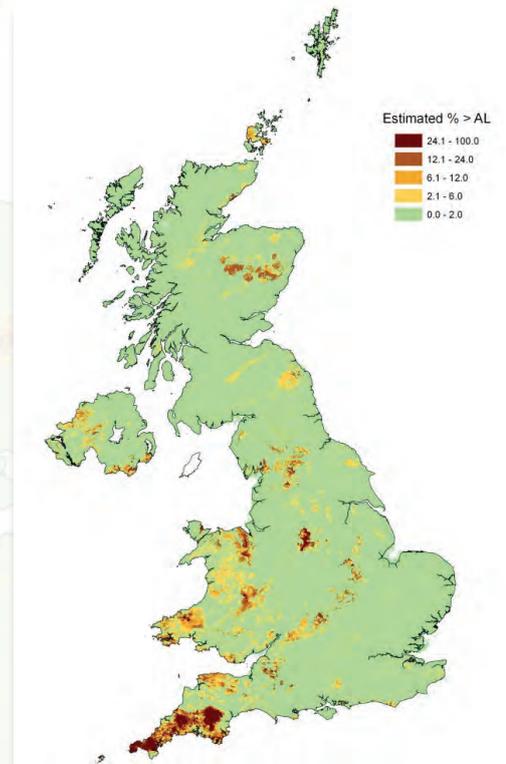
The current radon potential maps indicate the probability that new or existing houses will exceed the UK Action Level of 200 Bq m^{-3} . The maps cannot predict the actual radon level in any individual building, but can be used:

- to assess whether radon protective measures may be required in new buildings
- for cost-effective targeting of radon monitoring in existing dwellings and workplaces; and
- to provide a radon risk assessment for homebuyers and sellers.

Once identified as being in a high risk area, homes and workplaces can have the radon levels measured and if found to be high, remedial work undertaken.

Secondary hazards

Radon dissolved in groundwater can migrate over long distances along fractures and caverns depending on the velocity of fluid flow. Mains water supplies pass through treatments which tend to remove radon gas but small public water



Radon potential map of the UK showing the percentage of dwellings estimated to exceed the radon Action Level (AL) of 200 Bq m^{-3} . Image © NERC.

works and private domestic wells often have closed systems and short transit times that do not remove radon from the water or permit it to decay. In such situations, radon from the domestic water could add radon to the indoor air.

Apart from lung cancer, there is no epidemiological proof of radon causing any other type of cancer. However, the dose to the stomach from ingested radon can be significant and implies an increased risk of stomach cancer.

Scenarios for future events

Very high indoor radon concentrations (5000 to $17\,000 \text{ Bq m}^{-3}$) have been measured in UK homes but it is possible higher concentrations may be found in the future. Household energy efficiency drives that decrease ventilation (e.g. better sealed windows and doors) could lead to an increase in exposure to radon.



Monitoring and response by BGS

The BGS and HPA have produced a series of radon maps showing Radon Affected Areas, based on the underlying geology and indoor radon measurements. Access to accurate radon maps is clearly essential to enable preventative (protective) measures to be installed in new dwellings, help identify houses with radon above the Action Level which need to be remediated and to allow measurement campaigns and public awareness to be targeted on areas at greatest risk. The radon map data helps local authorities to communicate quickly and effectively with existing homeowners or developers planning to build new homes in high radon areas.

This is achieved by the online reports services developed by BGS and the HPA:

- For existing homes smaller than 25 metres and with a valid postcode, a Radon Risk Report can be ordered online from the UK Radon website (<http://www.ukradon.org/>)
- For existing homes greater than 25 metres, other large buildings and plots of land, a GeoReport can be ordered from BGS (<http://shop.bgs.ac.uk/georeports/>)

References

1. Appleton, J D, and Ball, T K. 1995. Radon and background radioactivity from natural sources: characteristics, extent and relevance to planning and development. *British Geological Survey Technical Report, WP/95/2*.
2. Appleton, J D, and Miles, J C H. 2005 Radon in Wales. In: *Urban Geology of Wales, Volume 2*. Nicol, D, and Bassett, M G (editors). National Museum of Wales Geological Series. (Cardiff: National Museum of Wales.)
3. Appleton, J D, Miles, J C H, and Young, M. 2011a. Comparison of Northern Ireland radon maps based on indoor radon measurements and geology with maps derived by predictive modelling of airborne radiometric and ground permeability data. *Science of the Total Environment*, 409, 1572–1583.
4. Gray, A, Read, S, McGale, P, and Darby, S. 2009. Lung cancer deaths from indoor radon and the cost effectiveness and potential of policies to reduce them. *British Medical Journal*, 6 January 2009.
5. HPA. 2009. Radon and Public Health (RCE-11): Report prepared by the Subgroup on Radon Epidemiology of the Independent Advisory Group on Ionising Radiation. Health Protection Agency, June 2009.
6. Miles, J C H, and Appleton, J D. 2005. Mapping variation in radon potential both between and within geological units. *Journal of Radiological Protection*, Vol. 25, 257–276.
7. Rees D M, Bradley E J, Green B M R G. 2011. HPA-CRCE-015 - *Radon in Homes in England and Wales: 2010 Data Review* ISBN 978-0-85951-688-4. (Chilton, UK:HPA)
8. Scheib, C, Appleton, J D, Miles, J C H, Green, B M R, Barlow, T S, and Jones, D G. 2009. Geological controls on radon potential in Scotland. *Scottish Journal of Geology*, Vol. 45(2), 147–160.
9. Watson, S J, Jones, A I, Oatway, W B, and Hughes, J S. 2005. HPA-RPD-001 — *Ionising Radiation Exposure of the UK Population: 2005 Review*. ISBN 0-85951-558-3. (Chilton, UK: HPA.)

Partnerships and links

Health Protection Agency, Centre for Radiation, Chemical and Environmental Hazards, Chilton, Didcot. Oxfordshire OX11 0RQ <http://www.hpa.org.uk/>

Ukradon: The UK reference site on radon, from the Health Protection Agency <http://ukradon.org/>

Further information

Contact the BGS Radon team by:
Email – enquiries@bgs.ac.uk
Telephone – 0115 9363143