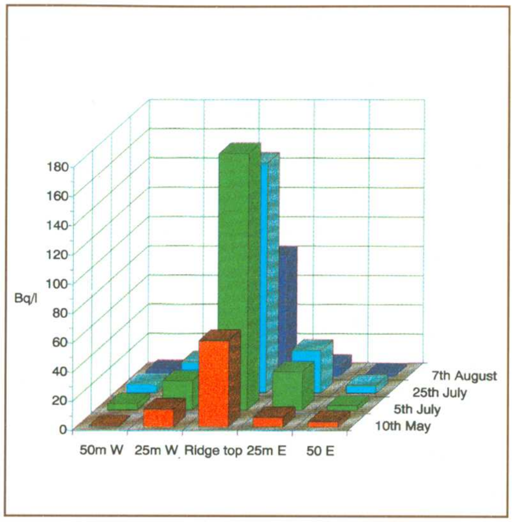
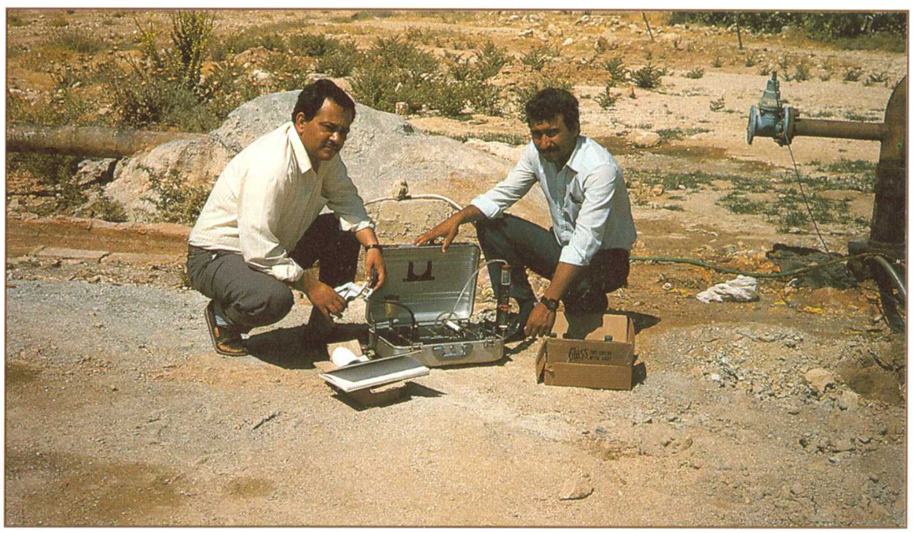


Radon levels measured on a traverse close to Taal crater, Philippines.

A radon emanometer, an instrument which counts alpha particles.

Sampling groundwater during a radon survey in Jordan



Zinc sulphide scintillation counting.

When alpha particles interact with zinc sulphide, they produce pulses of light which may be counted electronically. Because of the different half lives of radon, thoron and their immediate daughter products, it is possible to calculate the activities of both radon and thoron. This technique is commonly used for the measurement of radon in soil gases and the large number of instruments of this kind on the market attests to its suitability for field measurements.

Alpha track registration

Alpha particles may be detected by cellulose nitrate films which is damaged by the particles but is insensitive to light. The tracks of alpha particles are "developed" by etching the exposed film with caustic alkali. The track density is proportional to the radon concentration. Absolute calibration is possible by the use of standard radon generators and very close attention to uniformity of processing. The sensitivity may be increased simply by allowing a longer exposure time. This procedure is preferred for determination of radon levels in buildings because it allows longer sampling times.

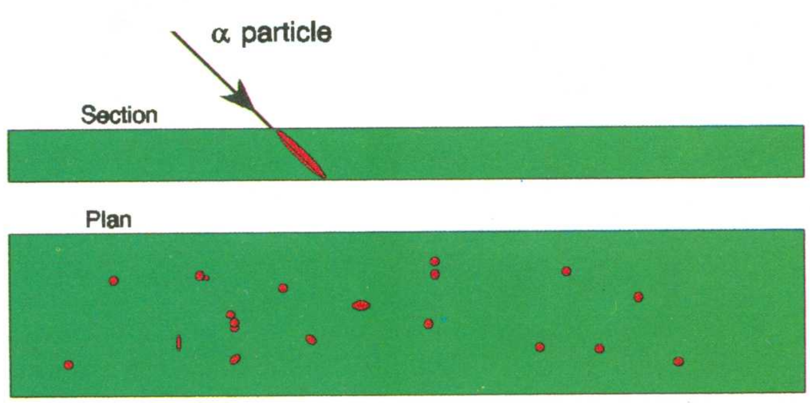


Diagram illustrating the way in which α particles damage cellulose nitrate film

Liquid scintillation counting

An organic fluorescence agent is dissolved in an organic solvent, usually a water immiscible liquid such as xylene or toluene. Many organic solvents are efficient extractors of radon from gas or liquid phases or absorbers. The ionisation of the solvent by alpha and beta particles and its subsequent de-excitation results in light emission which is proportional to the radon extracted. The procedure is laboratory based and requires expensive equipment, but it is possible to achieve a high through-put. There are many advantages to this approach to water measurements since the number of handling steps is low.

Semi-conductor detectors

Because of the lack of penetration of alpha particles, surface barrier semiconductor detectors are suitable for radon and radon daughter measurements. Alpha particles interact with the semiconductor depletion layer to produce a pulse of current. Suitable circuits then record the number of pulses. Although generally the practical surface area is much less than that of a zinc sulphide screen, use has been made of this technique for long term monitoring despite its lower count rate.

Absorbers.

Absorbers of various kinds, eg silica gel, activated charcoal, charged metal plates, can concentrate radon and/or its decay products. After a suitable elapsed time the build up of the radioactivity of the daughter products may be determined by extraction of the radon into a liquid scintillator or by detection of the gamma activity of the daughter Bi-214. A disadvantage of the latter procedure is that a low gamma background has to be achieved within a lead castle. Many absorbers such as charcoal appear to saturate or reach equilibrium with the radon rich gas.

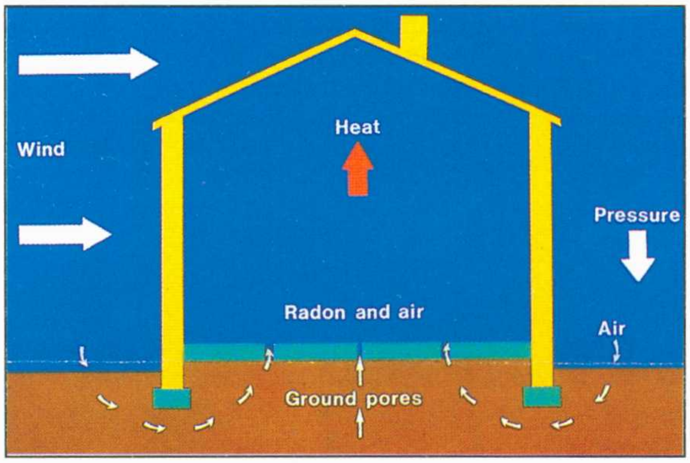
how radon enters confined spaces

A report (1991) by the UK-based Building Research Establishment lists the following main ingress routes:

cracks in solid floors;
construction joints;
cracks in walls below ground level;
gaps in suspended concrete or timber floors;
gaps around service pipes and
cavities in walls.

radon distribution maps

It has been shown that despite the inevitable variations in radon flux due to the weather, the controls of radon generation due to the type of bed-rock and/or soil may be considerably greater. In other words the between site or between bed-rock variation is greater than the within site variation. It is possible to produce maps, based upon geological knowledge, showing the levels of radon in soil gas in relation to rock types, with reasonable repeatability. Such radon surveys should be undertaken in as stable weather conditions as possible.



The ingress of radon into a typical house

In the U.K. at least, soil gas surveys based on adequate geological knowledge must be regarded as the most efficient means of estimating the radon potential of an area. The survey must cover the ground adequately, and should pay particular attention to those rock formations which underlie zones of high population density. Each rock formation, and its variants should be tested several times and some traverses should be repeated to test the variability. Typical sites should be monitored daily to determine variability due to weather. In cool temperate climates the best time for the survey is during the spring to autumn months, when the soils are less wet and are thus more permeable. Soil gas surveys at these times relate better to the dry conditions beneath houses during the winter months when domestic radon levels are highest.

mineral exploration

Traditionally, radon measurements in soil gases have been used to locate buried uranium deposits. Some non-uranium mineral deposits can be located by virtue of their small but enhanced uranium concentrations while others can be recognised by the fact that the uranium and consequently radon values are reduced by comparison with the host rock, eg tin and china clay deposits in granite.

finding geological faults

There is often an increased content of radon in soil gases over geological faults owing to the increased fluid flow along fault planes. Rocks of different permeability and uranium content may be juxtaposed and in this case radon mapping may help in locating the fault plane or the junction between the rock types. The whereabouts of faults is important in earthquake-prone areas for eliminating sites unsuitable for buildings.

prospecting for geothermal energy

Gas geochemistry has been shown to be of value in the field-evaluation of geothermal energy potential. Most geothermal areas are associated with volcanoes and high fluxes of gases such as carbon dioxide and radon are observed, usually from fumaroles. In any assessment of the extent of a geothermal field it is important to consider the more subtle manifestations of geothermal activity. Gas geochemical procedures are now standard in the location of geothermal activity associated with structures which cannot be seen at the suface because of burial by recently deposited overburden.

Radon to carbon dioxide systematics can be used for a preliminary assessment of the permeability of geothermal fields

predicting earthquakes and volcanic eruptions

Increased volcanic activity is usually accompanied by increasing levels of gas in fumaroles and faults. The monitoring of gases from such features, and from soils, can be used to predict eruptions since increases in gas output, and in the radon to carrier-gas ratios, often precede eruption. The main advantage of using gas measurement techniques for this is that the equipment may be automated, enabling monitoring to be carried out remotely. The results for a radon survey on the Taal Volcano in the Philippines are shown on page 13. These indicate a change in the levels of soil radon associated with increased volcanic activity during mid-June 1990.

Changes in radon levels over active faults have also been related to seismic activity and careful measurement of radon and other gases may help with earthquake prediction.

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Designed and produced in the British Geological Survey, International Division
Dr R D Walshaw, Editor
Printed by Saxons Graphics Ltd., Derby, England