Radon

Precautions for new buildings

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AGES

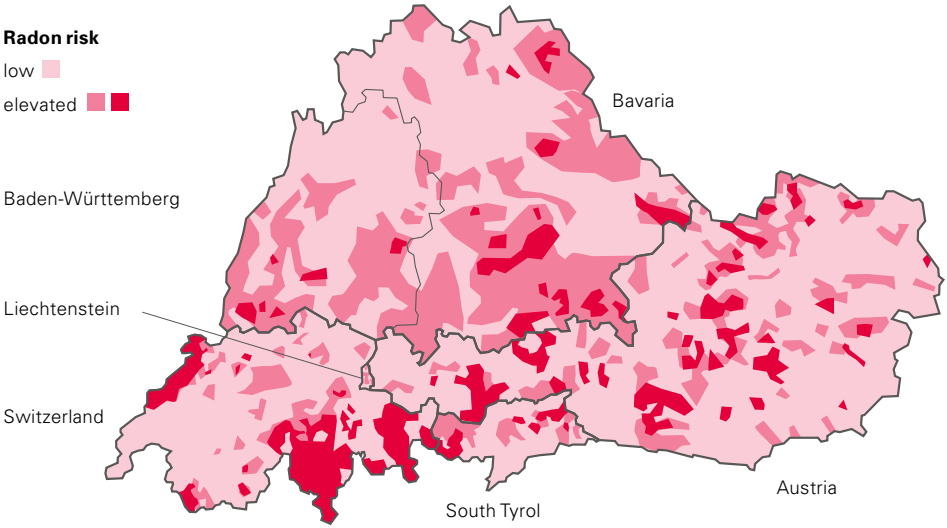
Properties, occurrence and effect of radon

Properties and occurrence

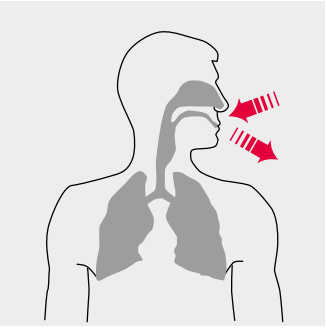
Radon is a natural, ubiquitous radioactive noble gas that is colourless, odourless and tasteless. It is a decay product of the radioactive heavy metal uranium, which is found in soil and rocks. Radon can escape relatively easily from soil and rocks, from where it spreads through gas in the soil or in dissolved form in water. In the process it can also penetrate the air inside buildings.

The radon potential maps and radon risk maps that have been produced for some countries will give you initial information about the likelihood of elevated radon concentrations being present inside buildings in your region.

The illustration below is a greatly simplified representation of the radon risk regions in Austria, southern Germany, South Tyrol, Liechtenstein and Switzerland.



More detailed information about radon can be found on the websites hosted in the individual countries. The relevant internet addresses are given on the back of this brochure.



Effect on health

Radon and its decay products are the second most common cause (approx. 10%) of lung cancer after smoking (approx. 85%).

Most of the radon gas inhaled in air is exhaled again straight away. The biggest risk to health is therefore not the radioactive noble gas radon itself, but its short-lived decay products – which are also radioactive heavy metals. The free decay products in the air inside rooms attach to particles floating in the air (aerosols).

When a person breathes in, the free decay products and aerosols are deposited in the lungs. Once inside the lungs, they emit ionising radiation which can damage the lung tissue in the immediate vicinity and can ultimately cause lung cancer.

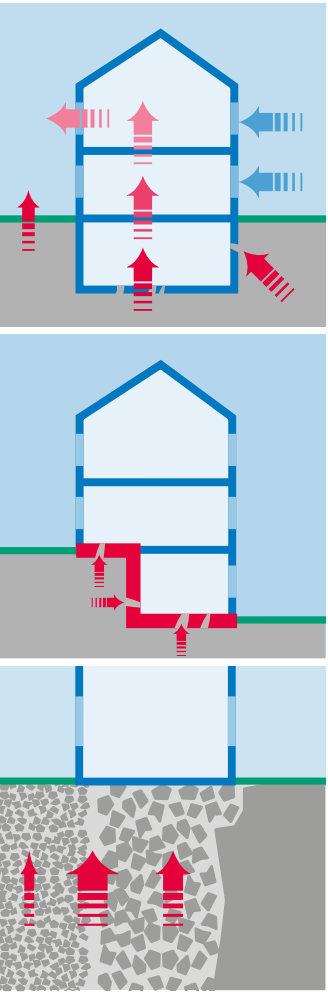
Guideline and limit values

The following table shows the guideline and limit values currently in force for annual mean radon concentrations inside inhabited rooms in the various countries.

Country	Guideline values		Limit values
	New buildings	Existing buildings	
Baden-Württemberg Bavaria	250 Bq/m³	250 Bq/m³	—
Austria	200 Bq/m³	400 Bq/m³	—
Switzerland	400 Bq/m³	400 Bq/m³	1000 Bq/m³
South Tyrol	200 Bq/m³	400 Bq/m³	500 Bq/m³ (for workplaces)

Annual mean radon concentrations normally range from 50 to 500 Becquerel per cubic metre (Bq/m³) of air. However, concentrations may reach several thousand Bq/m³, especially in regions where the radon risk is high.

Factors affecting the radon concentration inside rooms



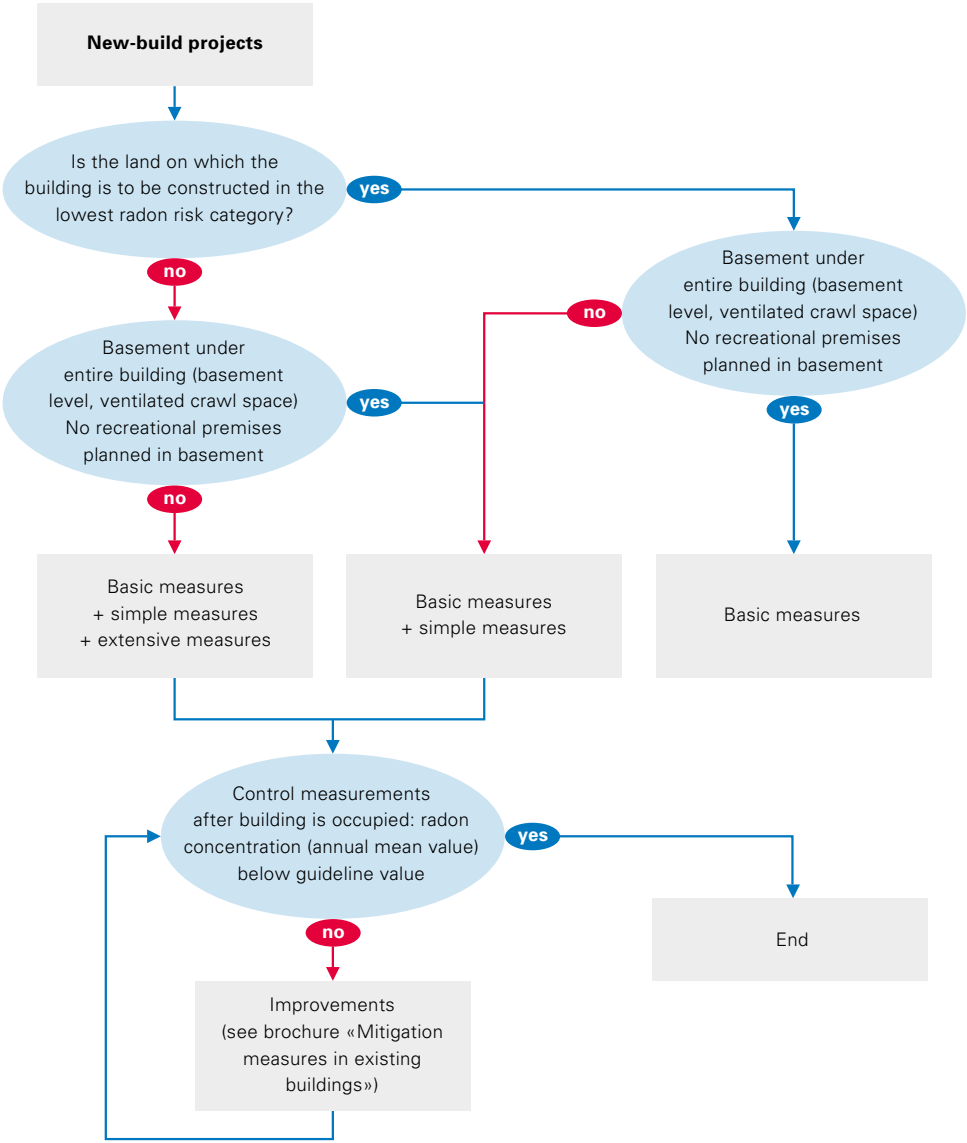
The radon concentration in the air inside rooms depends on a number of factors:

Air renewal in the building
The rate at which the air inside rooms is exchanged for outside air has a major effect on the radon concentration in rooms. Windows and doors which are not air-tight lead to a greater rate of air renewal. If air renewal is reduced, however – for example by fitting windows and doors which shut tightly – the concentration of radon in the room air may increase substantially.

The condition of the building
The fundamental issue is the permeability of the building to gas in the soil around the foundations and in walls which are in contact with the soil. Gas can penetrate through cracks and gaps and along wire and pipe conduits. Radon-containing soil gas is sucked into the building by the low-pressure zone that develops inside the building (chimney effect as a result of temperature differences between room air and external air, and due to wind pressure) – see illustration at top left.
If the basement or other soil-contacting parts of the building are open to higher storeys, this makes it particularly easy for radon to spread upwards.

Type of ground beneath the building
Apart from the composition of the soil and rock (uranium, radium content), other characteristics which play an important role are the particle size of the rock (which determines its ability to emit radon into the soil gas) and the permeability of the subsoil (which determines how the radon-containing soil gas is transported).
Particular caution is required in buildings constructed on scree or other slopes, weathered granite, karst or gravelly soils. Very compact soils and clay soils require less caution.

What precautions are necessary and when?



Precautions during construction

Preventive measures are considerably simpler, more effective and cheaper in the longer run than a subsequent radon mitigation in an existing building.
The basic principle is that the tighter the envelope of the building is where it is in contact with the soil, the lower the radon risk will be.

Precautions against radon should always be planned in collaboration with radon consultants, building experts and engineering companies.

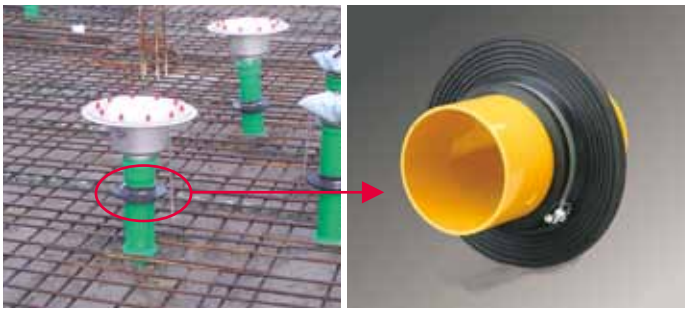
Basic measures

It is important to comply with existing legal requirements concerning water penetration and rising damp. Buildings with recreational premises and buildings whose purpose requires radon prevention measures to be employed must be protected permanently against water and damp penetrating or rising from the soil. Special attention must be paid to sealing conduits which penetrate parts of the construction in contact with the soil.

Earth probes for heat pumps represent a potential portal of entry for radon because they penetrate the soil so deeply. It must always be ensured that conduits through parts of the building which are in contact with the soil are sealed, for example by using a pipe duct system (PDS).

On the left: Example of a drain pipe passing through a foundation slab

On the right: Construction detail



Where ground-heat exchangers, aerial wells and similar systems are to be installed, it must be ensured that no radon-containing air from the soil enters the building through the ventilation system.

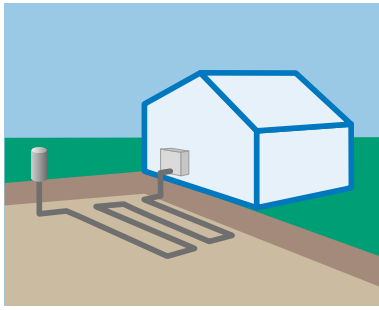
For this reason, ground-air heat exchanger systems must be installed with air-tight pipes (plastic) and tight seals. An alternative to air-tight construction would be to pressurise the horizontal loop.

Where an aerial well is installed, the gravel packing must be contained to the sides and underneath by an impermeable layer (impermeable soil such as clay; radon barrier). Suitable precautions must be taken for extracting water from the aerial well (e.g. installation of a pump or siphon). In this case it is vital to carry out control measurements to check the annual mean concentration of radon in the building.

All openings in foundation slabs – such as sewer clean-out pipes – must always be sealed gas-tight.

On the left: Correct installation

On the right: Incorrect installation



On the left: PDS – pipe duct systems

On the right: Ground-air heat exchanger systems must be constructed with air-tight pipes (plastic).

Simple measures

1. There is a basement under your entire house (basement level, ventilated crawl space), the house does not have any recreational premises that are in contact with the soil, and is not in the lowest radon risk category:

The basement should be sealed off from the inhabited parts of the building by means of measures such as:
- Self-closing, air-tight door between the basement and the inhabited area.
- Professional sealing of any openings (e.g. conduits for water, electricity, heating) through the basement ceiling.
- Sealing of installation ducts, elevator shafts and chutes (e.g. for laundry).
- Basement rooms with a soil floor should be sealed off from other parts of the house particularly carefully and should preferably be accessible only from the outside.

Conduits for electricity, water, waste water etc. passing into and out of the building through construction elements in contact with the soil must be placed in a sealed construction (e.g. PDS).

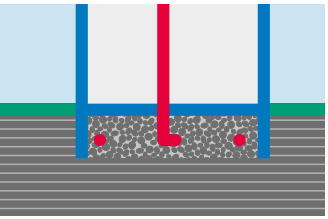
2. Your house has recreational premises that are in contact with the soil and is in the lowest radon risk category:

In addition to the basic measures, particular attention must be paid to the following:
- Continuous foundation slab and walls in contact with the soil constructed of concrete of exposure class XC2 or higher; alternatively sub-floor suction system can be installed (see *Extensive measures* on page 9).
- Conduits for electricity, water, waste water etc. into and out of the building through soil-contacting construction elements must be placed in a sealed construction (e.g. PDS).

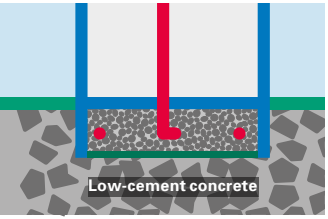
If there is a basement under only part of your house, the measures under point 1 must be adopted for the part with a basement, and the measures under point 2 must be adopted for the part with no basement.

Extensive measures

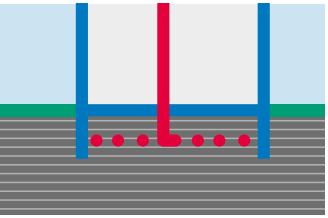
Schematic representation of a radon extract system in different permeability situations:



Construction in ballast or a gravel bed (up to 8 m between pipes)



Low-cement concrete in highly permeable ground



Construction in the ground (1 to 3 m between pipes)

Sub-floor suction (radon extract system)

The main purpose of this measure is to create a low-pressure zone beneath the foundation slab (lower than the pressure in the building). This prevents convection-driven penetration of radon from the soil.

Conduits for electricity, water, waste water etc. into and out of the building through construction elements in contact with the soil must be placed in a sealed construction (e.g. PDS).

Extract pipes with a diameter of 10 cm must be laid under the continuous foundation slab respectively the floor slab (if a foundation has been laid with footings). The way in which the pipes are laid is determined by the permeability of the surrounding material. If gravel or ballast has been incorporated into the foundation, the pipe system is laid in an S-shape with a distance of up to 8 m between the pipes, which should then converge at a vent pipe (solid-wall pipe).

If the pipe system is installed in the ground (pipes have to be protected by gravel and/or fleece), a smaller distance of 1 to 3 m is required. The pipe system must be at least 1 to 2 m clear of external walls. Air from the water drainage system must be prevented from entering the radon extract system as it will otherwise prevent negative pressure building up (the systems must be separated by the foundation or radon barrier, for example).

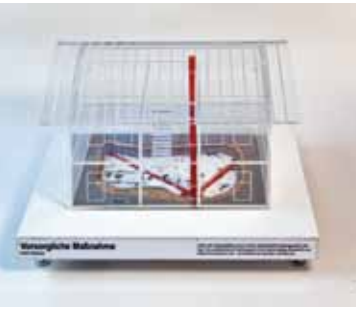
Note on sub-floor suction in highly permeable soils
Where the ground consists of ballast or is heavily eroded (e.g. in regions with karst soil), it is not possible to create a low-pressure zone under the foundation slab unless additional measures are employed. In such cases the permeability between the extract system and the ground must be reduced radically by laying low-cement concrete under the radon extract system.

Ways of constructing the vent pipe for the radon extract system

– Full-wall pipe with a diameter of at least 15 cm venting through the roof (in the piping duct, for example). This version makes use of the negative pressure created by the chimney effect in the vent pipe (the vent pipe needs to be thermally insulated in the attic). Advantages: Passive creation of negative pressure, no fan operating costs.
– To prepare for active creation of negative pressure with a fan, a full-wall pipe with a diameter of at least 10 cm is inserted through the floor slab, fitted with an air-tight seal and labelled as a radon vent pipe.

Note: If the floor slab is not constructed as a continuous foundation slab (exposure class XC2 or higher), preference should be given to the first method.

If the control measurement reveals an elevated radon level, a fan must be incorporated into both methods to actively create negative pressure. It is vital to take account of the formation of condensation in the piping and the noise generated by the fan. The roof vent should be at least 2 metres away from windows and doors.



Model on the left: Sub-floor suction, vented through the roof (full-wall pipe with a diameter of at least 15 cm)

On the right: Incorporation of a radon extract system in gravel respectively ballast

Inlet vent for controlled ventilation of inhabited rooms (at least 80 cm above ground level)

Air-tight building envelope and controlled ventilation of inhabited areas

Controlled room ventilation is not sufficient as an extensive protective measure against radon in new constructions unless the building envelope is air-tight enough. In this case, sub-floor suction must be incorporated as a precaution.

A building envelope is adequately air-tight if the n50 air leakage rate is less than 0.6 h-1 (which corresponds to various standards for low-energy houses, such as the passive house, gold-class ClimateHouse and Minergie-P).

The ventilation system must be operated at neutral pressure or with a slightly positive pressure (a few Pa).

The fresh air intake outside the building must be at least 80 cm above ground level (air must not be drawn in through the shafts outside basement windows, for example).

Facts and notes

- Radon is the second most common cause of lung cancer after smoking
- Failure to take precautions means a higher radon risk
- Prevention is simple, effective and low-cost
- National radon risk maps provide initial information
- Building envelopes which are air-tight to the ground lower the penetration of radon
- A simple radon extract system provides protection in risk areas

Information about radon

Brochures in this series

- Radon – Precautions for new buildings
- Radon – Measurement and evaluation
- Radon – Mitigation measures in existing buildings
- Radon – The effect of retrofitting thermal insulation

On the internet

Germany: www.bfs.de (search for *Radon*)
- Baden-Württemberg: www.uvm.baden-wuerttemberg.de (search for *Radon*)
- Bavaria: www.lfu.bayern.de (search for *Radon*)

Austria: www.radon.gv.at
- Upper Austria: www.land-oberoesterreich.gv.at/Thema/Radon

Switzerland and Liechtenstein: www.ch-radon.ch

South Tyrol: www.provinz.bz.it/umweltagentur (search for *Radon*)

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