Radon

Mitigation measures in existing buildings

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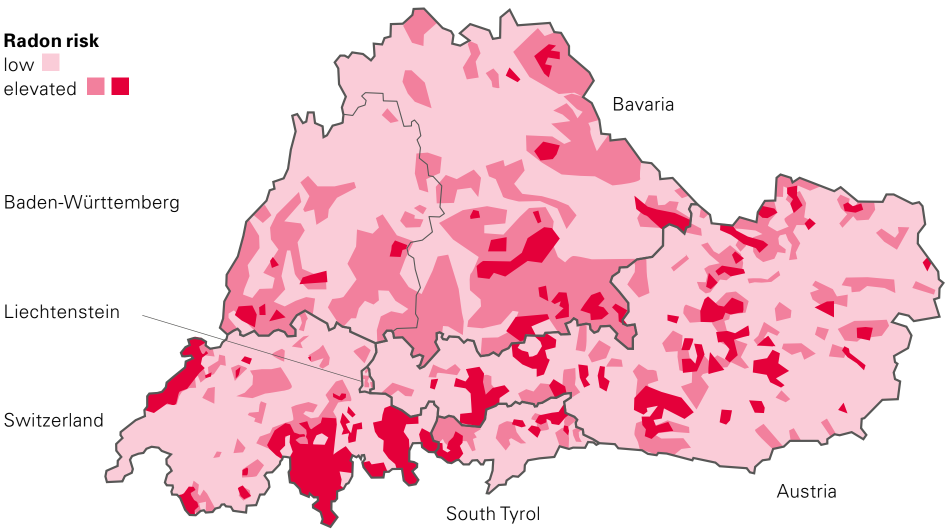
Properties, occurrence and effect of radon

Properties and occurrence

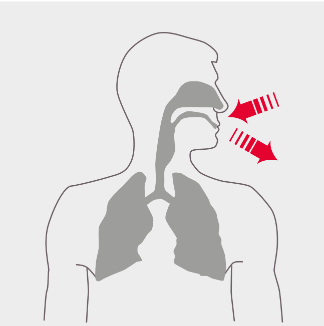
Radon is a natural, ubiquitous radioactive noble gas that is colourless, odourless and tasteless. It is a decay product of the radioactive heavy metal uranium, which is found in soil and rocks. Radon can escape relatively easily from soil and rocks, from where it spreads through gas in the soil or in 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

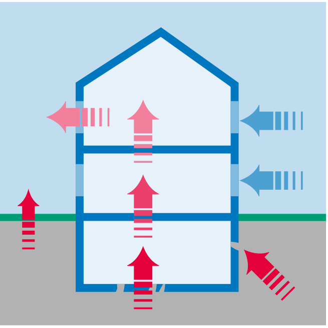
The following table shows the guideline and limit values currently in force for annual mean radon concentrations inside inhabited rooms in the various countries.

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)

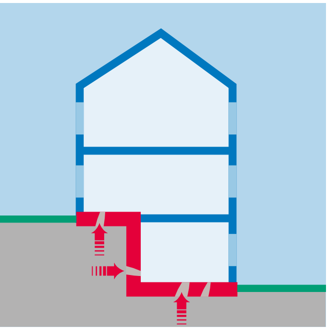
Annual mean radon concentrations normally range from 50 to 500 Becquerel per cubic metre (Bq/m^3) of air. However, concentrations may reach several thousand Bq/m^3, especially in regions where the radon risk is high.

Factors affecting the radon concentration inside rooms

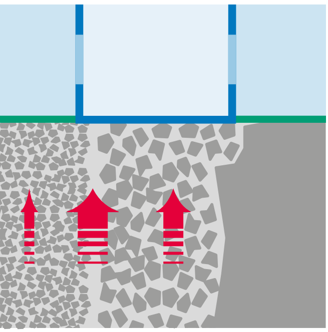
The radon concentration in the air inside rooms depends on a number of factors:



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 mitigation measures are necessary and when?

The urgency and extent of the measures depend on the radon concentration (annual mean level) measured in inhabited rooms. Its determination is explained in the brochure «Radon – Measurement and evaluation».

Radon concentration

Above guideline value shown in table on page 3

no → **Voluntary measures**

yes

Above 1000 Bq/m³

no → **Immediate measures:** Air rooms more intensively, possibly use them for a different purpose
Possibly temporary or simple construction measures

Completion of radon mitigation at the latest when future general renovation measures are carried out

yes

Above 5000 Bq/m³

no → **Immediate measures:**
Air rooms more intensively
Possibly use them for a different purpose
Possibly temporary or simple construction measures

Radon mitigation to be completed within **three** years

yes → **Immediate measures:**
Air rooms more intensively
Possibly use them for a different purpose
Begin mitigation measures

Radon mitigation to be completed within **one** year

Airing rooms more intensively

Permanent static ventilation of the basement (by leaving windows fully or tilted open) reduces the radon concentration in the basement and thus also in inhabited rooms. Attention must be paid to possible frost and mould formation.
Inhabited rooms should be aired by leaving windows wide open or cross-ventilating for 5 minutes 3 to 10 times a day, depending on the radon concentration measured (annual mean level), respectively by airing before using the rooms.
Windows should be left open or tilted open as often as possible when the heating system is not in operation.
Note: The radon concentration can return to its previous level as little as 2 hours or so after rooms have been aired.

Using rooms for a different purpose

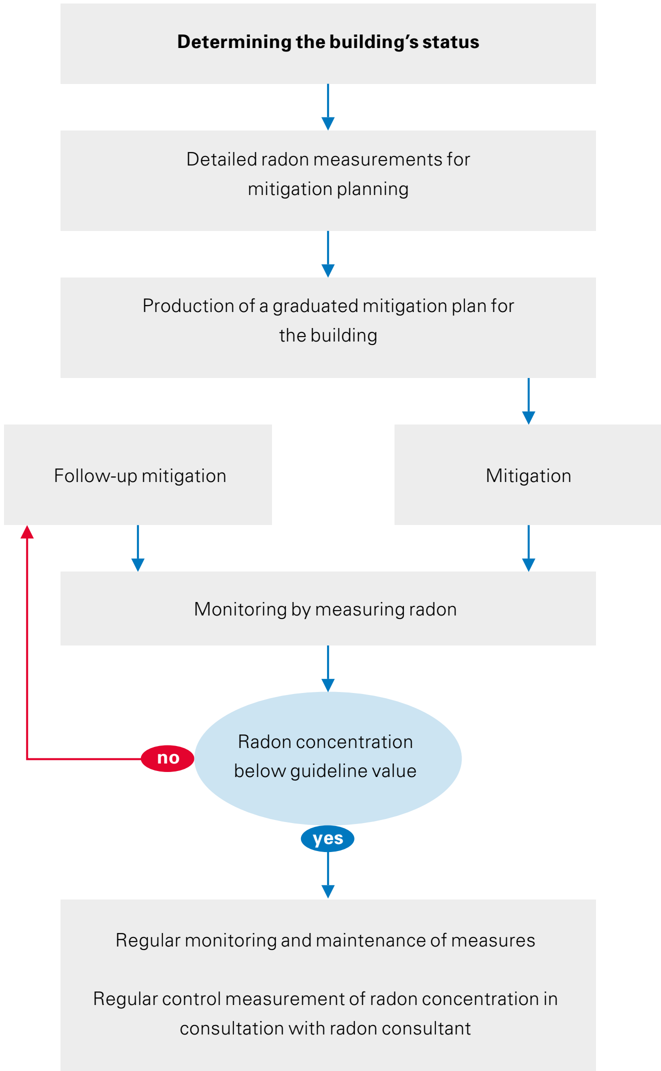
This means only using affected rooms for purposes which do not require people to be present except for short periods. This solves the problem without resorting to mitigation methods.

Leaving windows wide open or cross-ventilating for 5 minutes, respectively airing rooms before use, reduces the radon concentration.

A living room or office can be turned into a room in which people do not remain for more than short periods (e.g. a storage room).

Radon mitigation

Radon mitigation measures shall be planned in collaboration with radon consultants, building experts and engineering companies.



Graduated mitigation plan

Production of a graduated mitigation plan

Are affected rooms in contact with the soil?

no →

Basic measures

- Seal basement, crawl space or cavities from inhabited parts of the building
- Close visible openings, cracks etc. in parts of the building in contact with the soil

Further measures

- Equalise indoor pressure with outdoor pressure
- Create low-pressure zone in basement/crawl space
- Sub-slab suction (radon suction pit)
- Mechanical ventilation system

yes ↓

Mitigation with completely new underfloor construction conceivable/planned

no →

Basic measures

- Close visible openings, cracks etc. in parts of the building in contact with the soil

Further measures

- Equalise indoor pressure with outdoor pressure
- Sub-slab suction (radon suction pit)
- Mechanical ventilation system
- Suction under floors/between walls in individual rooms

yes ↓

Ground under building very permeable (e.g. ballast bed)

no →

Sub-floor suction (radon extract system)

yes ↓

Sub-floor suction (radon extract system) with sealing layer under the ballast bed

Mitigation methods

The recommended techniques for mitigating radon-burdened buildings are based largely on experience gained from radon programmes in Switzerland, South Tyrol, Austria and Germany.

In many cases the methods mentioned here are complementary, and it is worthwhile to use them in combination with each other. It is normally insufficient to simply seal the building.

Sealing basement, crawl space or cavities from inhabited parts of the building

Sealing reduces the penetration of radon from an uninhabited basement into inhabited parts of the building.

Sealing measures include:

- 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 built-in chutes (e.g. for laundry).
- Basement rooms with a soil floor should be sealed off from other parts of the house particularly carefully from the inside and should preferably be accessible only from the outside.

Sealing by constructing an air-tight enclosure for the basement stairs – before and after

Closing visible openings, cracks etc. in parts of the building in contact with the soil

Larger openings (penetrations, shafts etc.) and cracks in parts of the building in contact with the soil (walls, floor slab) must be closed. Shafts and conduits with caps which are not air-tight also provide a point of entry for radon.

Equalising indoor pressure with outdoor pressure

Soil gas which contains radon is sucked into the building by any low-pressure zone that develops inside the building (chimney effect as a result of temperature differences between room air and external air, or suction due to wind pressure).

An opening to the outside slightly above ground level reduces this low pressure. Examples: outside air openings, air elements in windows, core drilling through external wall with grating.

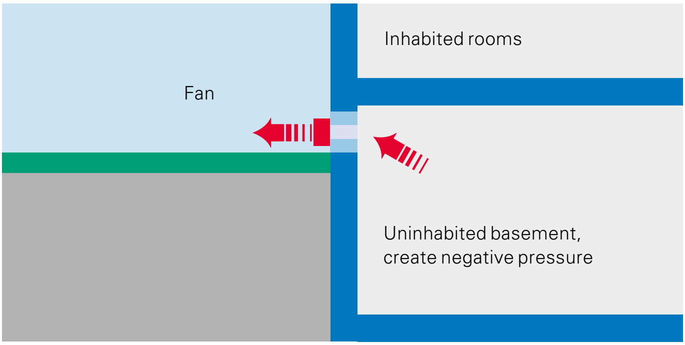
Larger openings and cracks in parts of the building in contact with the soil must be closed.

Outside air opening

Creating a low-pressure zone in the basement / crawl space

A small fan creates an area of low pressure in the basement or crawl space relative to the inhabited rooms, thus reducing radon penetration from the basement into the inhabited area. To create a low-pressure zone, the basement/crawl space must be sealed off from the inhabited area and from the outside (windows and doors closed).

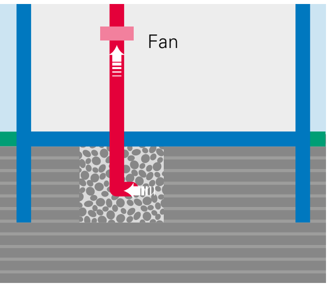
Important: The radon concentration in these basement rooms may increase sharply. Therefore this method is not suitable if people spend long periods in the basement rooms.



A small fan creates an area of low pressure in the basement or crawl space relative to the inhabited rooms.

Facts and notes

- Radon is the second most common cause of lung cancer after smoking.
- Radon penetrates from the ground into the building through places which are not air-tight.
- National radon risk maps provide initial information.
- The only way to be sure about the radon concentration in a building is by measuring it.
- There are simple, established mitigation methods.



Selective sub-slab suction vented through the roof

Renewal of the floor: incorporating a radon extract system

Sub-floor extraction

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

Sub-floor extraction can be employed successfully wherever a low-pressure zone can be created. It can be achieved, for example, by laying a bed of ballast directly beneath the foundation slab on top of compact soil.

Selective suction (radon suction pit)

Selective suction can be achieved by:

- Using cavities (utility shafts) in contact with the soil underneath the foundation slab
- Core drilling through the foundation slab (if there is a ballast bed under the slab)
- Digging out a pit (approx. 0.5 x 0.5 x 1 m)

In most cases it is sufficient to apply suction in one place (preferably in the centre of the house and/or in a room with a high radon concentration).

Comprehensive suction (radon extract system)

When the structure under the foundation slab is renewed, the old material is excavated to a depth of approx. 40 cm. Then extract pipes with a diameter of 10 cm are laid in the gravel bed under the raw concrete. The extract system is laid in such a way that suction is ensured across the whole area. The vent pipe must be a full-wall pipe.

Technical information on constructing a sub-slab suction system
The vent pipe must be a full-wall pipe with a diameter of at least 7 cm. It must penetrate an external wall horizontally or be fitted through the roof (for example in the utility shaft or through an open chimney). If the pipe vents through the roof, an attempt can be made to create a low-pressure zone by using a full-wall pipe with a diameter of 15 cm due to the chimney effect (the vent pipe must be thermally insulated in the attic). Advantages: passive creation of negative pressure, no operating costs for fan.

Selective suction (radon suction pit) – digging a pit

The possibility of condensation forming in the piping system and the noise created by the fan must be borne in mind. The roof vent should be at least 2 metres away from windows and doors.

Experience has shown that fans with a power rating of between 20 W and 100 W which create negative pressure of between 60 Pa and 500 Pa can be used successfully. Fans may be used intermittently (with a timer) if the radon situation permits.

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.

A fan outside the building creates slightly negative pressure under the foundation slab.

Mechanical ventilation system

This method is suitable for a radon mitigation in individual rooms, flats and inhabited buildings. The principle is based on the controlled introduction of fresh air and, more particularly, on the creation of slightly positive pressure of 1 to 2 Pascal. This means that doors, windows and other openings have to be sealed very tightly.

If the dimensions of larger air supply systems need to be determined, a test can be carried out – such as a blower door test – to establish the air supply rate required to create slightly positive pressure and the effect on the radon concentration.

Where heat-recovery ventilation systems are used, it must be possible to regulate the inbound and outbound airflow separately so as to create a high-pressure zone. It must be borne in mind that in this case the efficiency of the heat exchanger may be reduced significantly depending on the amount of excess inbound air required.

It is sufficient to install simple wall ventilators for a radon mitigation in individual rooms.

This measure can also have beneficial side effects on the air quality inside the rooms, for example regarding mould, carbon dioxide and volatile organic compounds (VOC).

A controlled supply of fresh air creates slightly positive pressure inside rooms/buildings (inside and outside)

Air intake for a mechanical air supply system

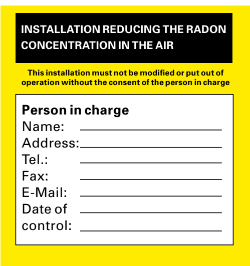
Suction under floors/between walls in individual rooms

Suction applied under floors requires the construction of a false floor in the affected rooms.
A continuous cavity about 1 cm high needs to be planned between the additional and the original floor in the room. The air in this cavity is extracted from the building either passively or actively (by using a fan) through a pipe system. Care must be taken to ensure that the top layer of the floor is constructed in such a way that it is sealed as tightly as possible against air passing into the room. The adjustment of the fan must be optimised to achieve a minimally lower pressure.

The above method can similarly be used for walls which are in contact with the soil.

Concluding remarks

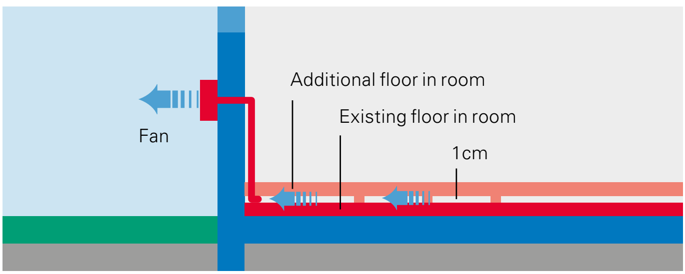
- In rare instances, radon mitigation methods involving negative pressure may lead to uncontrolled emissions of carbon monoxide if open sources of fire are present (wood-burning stoves etc.) Monitoring of the situation is recommended.
- All installations designed to reduce radon must be labelled clearly.
- Installations must be inspected and serviced regularly (seals, fans etc.) to ensure they operate correctly.


INSTALLATION REDUCING THE RADON CONCENTRATION IN THE AIR

This installation must not be modified or put out of operation without the consent of the person in charge

Person in charge
Name: ______
Address: ______
Tel.: ______
Fax: ______
E-Mail: ______
Date of control: ______

All installations designed to reduce radon must be labelled clearly



Sub-floor suction in a single room

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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