Radon

Precautions for New Buildings

Baden-Württemberg
MINISTERIUM FÜR UMWELT, KLIMA UND ENERGIEWIRTSCHAFT

Bavarian Environment Agency

UPPER AUSTRIA

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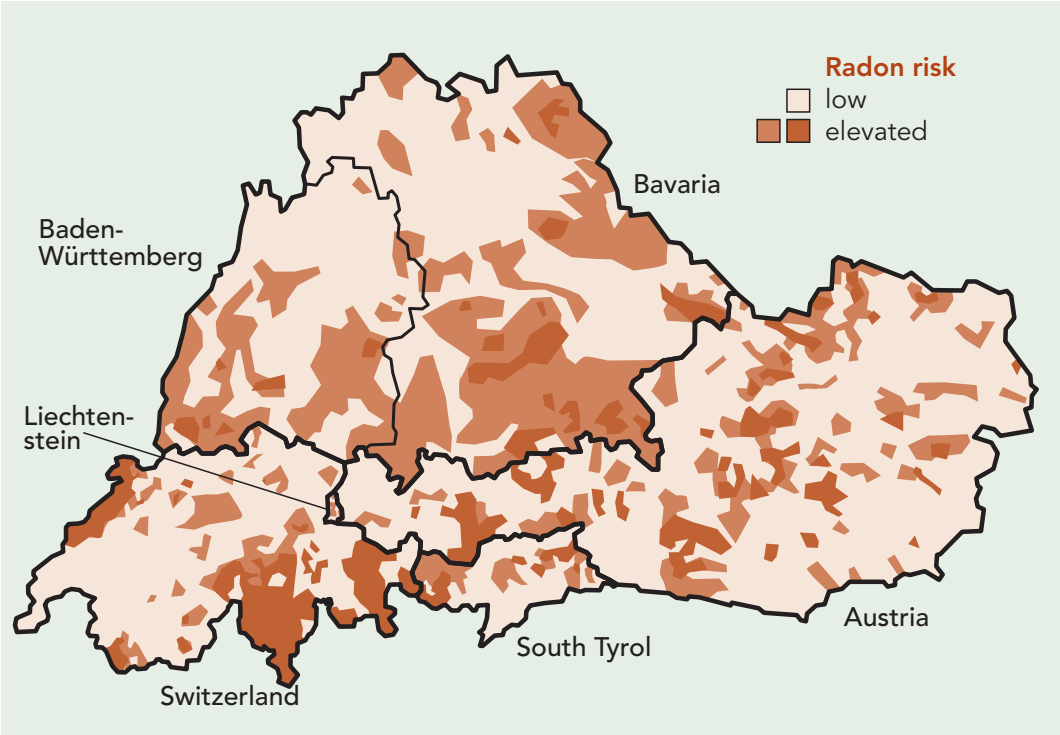
Properties, Occurrence and Effect of Radon

Properties and occurrence

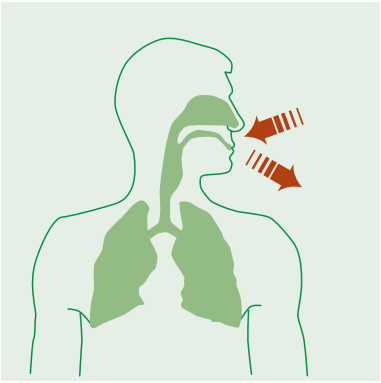
Radon is a natural, ubiquitous radioactive noble gas that is colourless, odourless and tasteless. It is a decay product of the radioactive heavy metal uranium, which is found in soil and rocks. Radon can escape relatively easily from soil and rocks, from where it is transported by soil gas or dissolved in water. By means of those processes radon can also enter buildings.

Radon potential maps and radon risk maps give initial information about the likelihood of elevated indoor radon concentrations in your region.

The illustration below is a greatly simplified representation of radon risk regions in Austria, southern Germany, South Tyrol, Liechtenstein and Switzerland.
More detailed information about radon can be found on the websites hosted by the individual countries. The corresponding internet addresses are on the back of this brochure.



Health impact



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

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

When a person inhales, the free decay products and aerosols are deposited in the lungs. Once inside the lungs, they emit ionising radiation which can damage the surrounding lung tissue and can ultimately lead to lung cancer.

Guideline and limit values

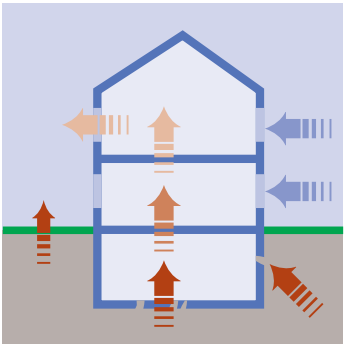
The following table shows the guideline and limit values for the annual mean radon concentration of inhabited rooms currently in force in various states.

State	Guideline values		Limit values
	New buildings	Existing buildings	
Baden-Württemberg Bavaria	250 Bq/m^3	250 Bq/m^3	–
Austria	200 Bq/m^3	400 Bq/m^3	–
Switzerland	400 Bq/m^3	400 Bq/m^3	1.000 Bq/m^3
South Tyrol	200 Bq/m^3	400 Bq/m^3	500 Bq/m^3 (at workspaces)

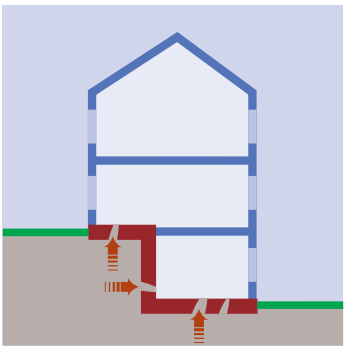
Annual mean radon concentrations are typically in the range of 50 to 500 Becquerel per cubic metre (Bq/m^3) of air. However, concentrations may reach several thousand Bq/m^3, especially in radon risk regions.

Factors Affecting the Indoor Radon Concentration

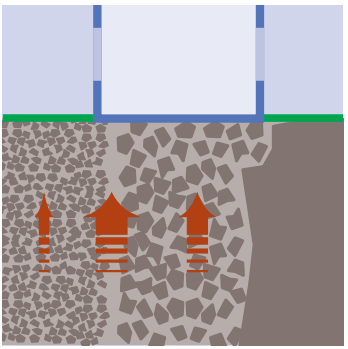
The indoor radon concentration depends on a number of factors:



- **Air exchange in the building:**
  The rate at which indoor air is replaced by outdoor air has a major effect on the radon concentration. Windows and doors which are not air-tight lead to a greater air exchange rate. If air exchange is reduced, however – for example by fitting windows and doors which close tightly – the concentration of radon in indoor air may increase substantially.

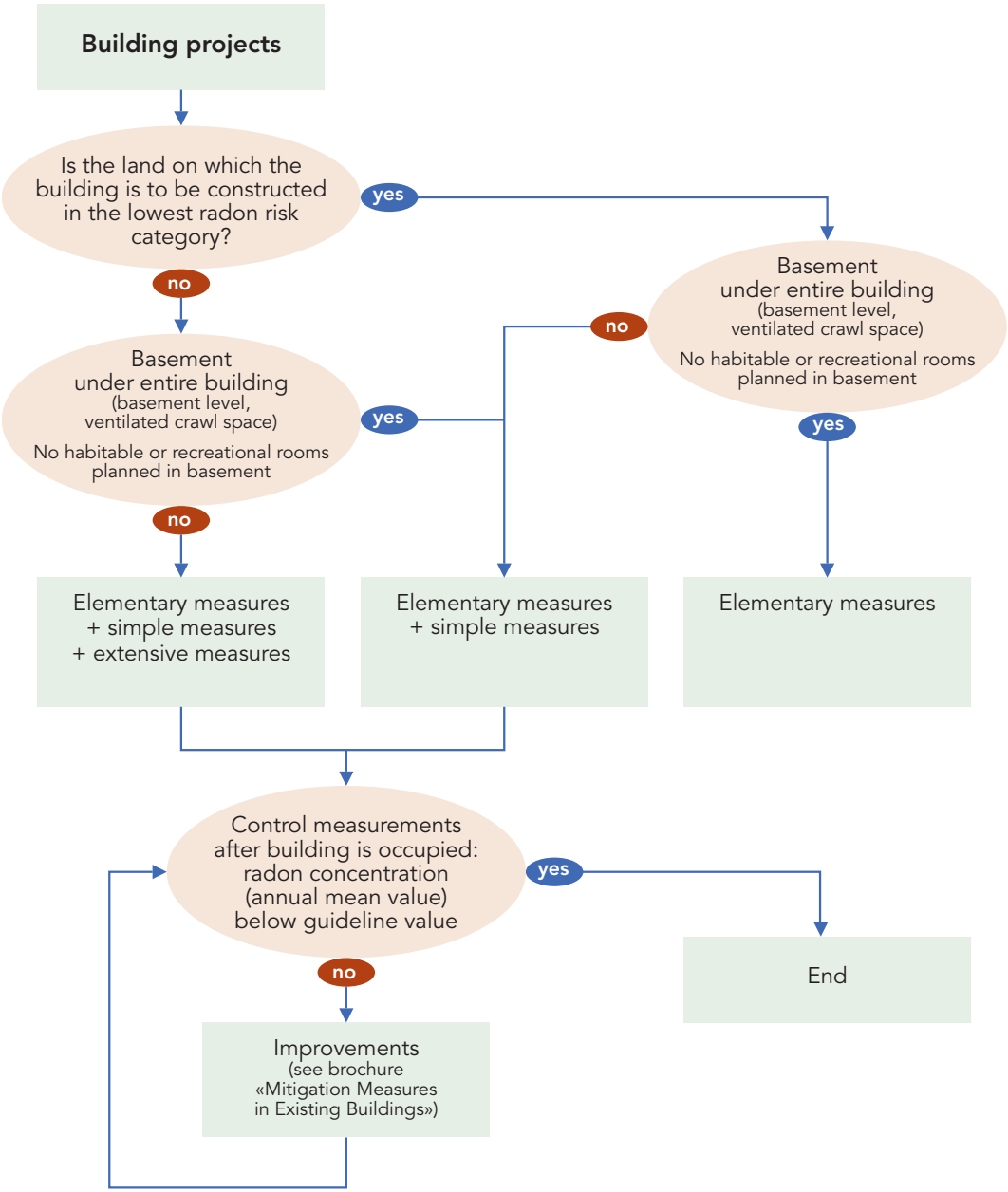


- **The condition of the building:**
  The fundamental factor is the permeability of the building to soil gas around the foundations and in walls which are in contact with the soil. Soil gas can penetrate through cracks, gaps and along wire and pipe conduits into the building. Radon-containing soil gas is sucked into the building by the depression zone that develops inside the building (stack effect as a result of temperature differences between indoor air and oudoor 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 soil. Very compact soil and clay soil require less caution.

What Precautions are Necessary and When?



Construction Precautions

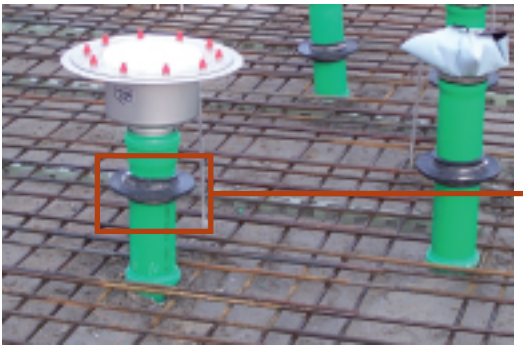
Preventive measures are considerably simpler, more effective and cheaper in the longer run than a subsequent radon mitigation in an existing building.
The basic principle is that the tighter the envelope of the building where in contact with the soil, the lower the radon risk will be.

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

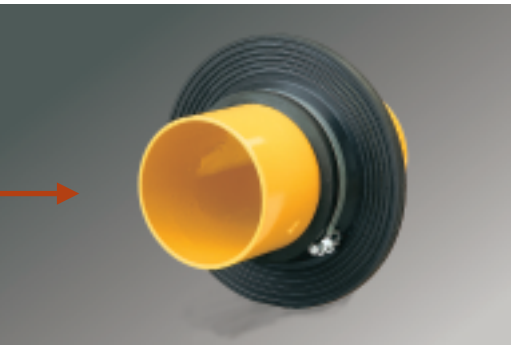
Elementary Measures

It is important to comply with existing legal requirements concerning water penetration and rising damp.
Buildings 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 entry path for radon due to their depth.
It must always be ensured that conduits leading through the building elements which are in contact with the soil are well sealed, for example by using a pipe duct system (PDS).



Example of a drain pipe passing through a foundation slab

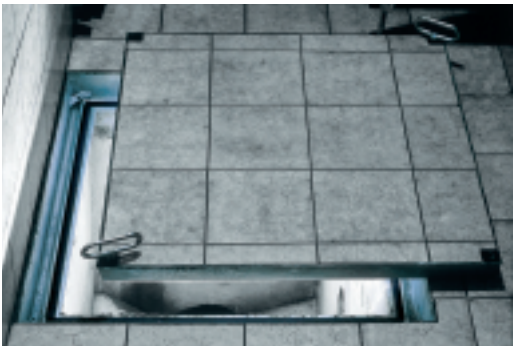


Construction detail

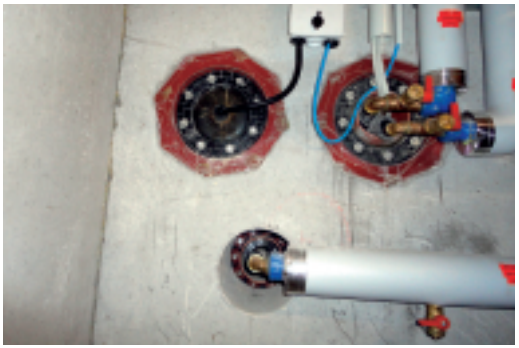
Where ground-heat exchangers, air wells and similar systems are to be installed, it must be ensured that no radon-containing air from the soil enters the building through the ventilation system.

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 earth tubes.

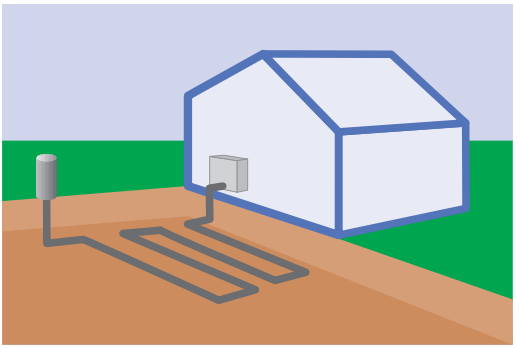
Where an air well is installed, the gravel packing must be contained to the sides and underneath by an impermeable layer (impermeable soil such as clay; membrane). Suitable precautions must be taken for the discharge of water from the air well (e.g. installation of a pump or siphon). In this case it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



All openings in foundation slabs – such as sewer cleanout pipes – must always be sealed air-tight
On the left: Incorrect installation, on the right: Correct installation



PDS – pipe duct systems



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 habitable or recreational rooms that are in contact with the soil, and is not in the lowest radon risk category:

The basement should be sealed off from inhabited parts of the building by 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 natural 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 habitable or recreational rooms 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 are to be constructed of concrete of exposure class XC2 or higher; alternatively a 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 only under a part of your house, the measures under point 1 must be applied to the part with a basement, and the measures under point 2 must be applied to the part without basement.

Extensive Measures

Sub-floor suction (radon drainage system)

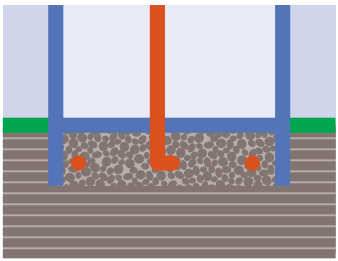
The main purpose of this measure is to create a depression zone beneath the foundation slab (lower than the pressure in the building). This prevents convection-driven entry of radon from the soil.

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).

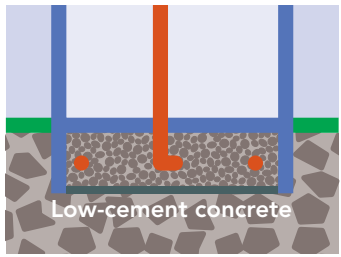
Drainage pipes with a diameter of 10 cm must be laid under the continuous foundation slab or the floor slab (if a foundation has been laid with footings). The way in which the pipes are laid is determined by the permeability of the surrounding material. If gravel has been incorporated into the foundation, the pipe system is laid in an S-shape with a distance of up to 8 m between the pipes, which should then converge to a vent pipe (full-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 drainage system as it will otherwise prevent negative pressure building up (the systems, for example, must be separated by the foundation or a membrane).

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

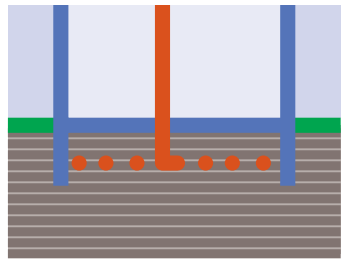
Schematic representation of a radon drainage system in different permeability situations:



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



Low-cement concrete layer in highly permeable ground



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

Ways of constructing the vent pipe for the radon drainage system:

- Full-wall pipe with a diameter of at least 15 cm venting through the roof (e.g. in the installation duct). This version makes use of the negative pressure created by the stack 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.
- In order to actively create a 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 into account the condensation in the piping and the noise generated by the fan.
The roof vent should be at least two metres away from windows and doors.

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

Incorporation of a radon drainage system in gravel

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 sufficiently air-tight. If this is not the case, sub-floor suction must be additionally installed 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, goldclass 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 (the air, for instance, must not be drawn in through the shafts in front of basement windows).

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

Facts and Notes

- Radon is the second leading 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 against the ground lower the radon entry rate
- A simple radon drainage 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*)
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Switzerland and Liechtenstein: **www.ch-radon.ch**
South Tyrol: **www.provinz.bz.it/umweltagentur** (search for *Radon*)

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