



Radon

Mitigation Measures in Existing Buildings



Baden-Württemberg

MINISTERIUM FÜR UMWELT, KLIMA UND ENERGIEVERSICHERUNG



Bavarian Environment
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Properties, Occurrence and Effect of Radon

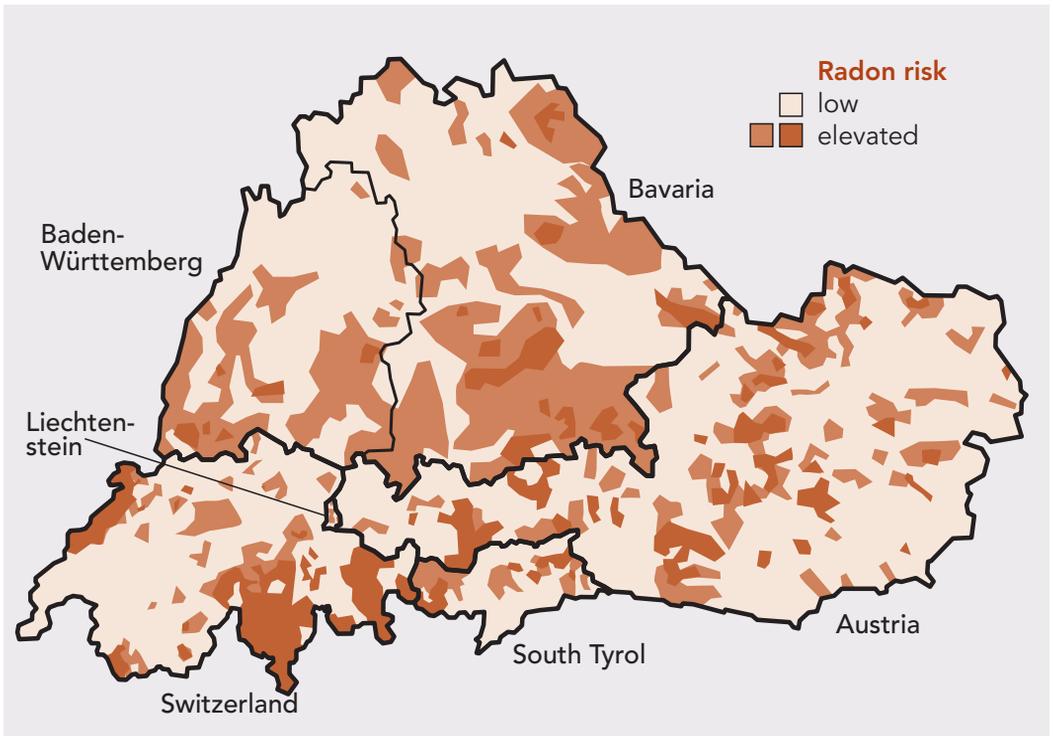
Properties and occurrence

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.

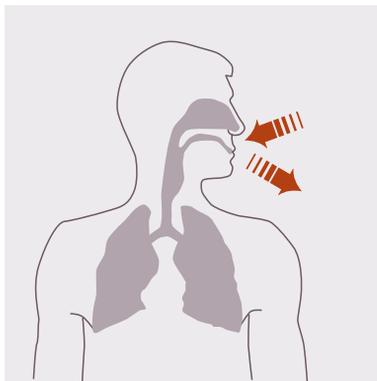
Radon potential maps and radon risk maps give initial information about the likelihood of elevated indoor radon concentrations in your region.

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

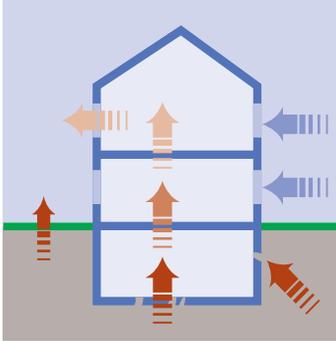
The following table shows the guideline and limit values for the annual mean radon concentration of inhabited rooms currently in force in various states.

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 workplaces)

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

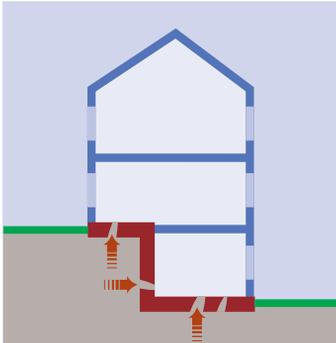
Factors Affecting the Indoor Radon Concentration

The indoor radon concentration depends on a number of factors:



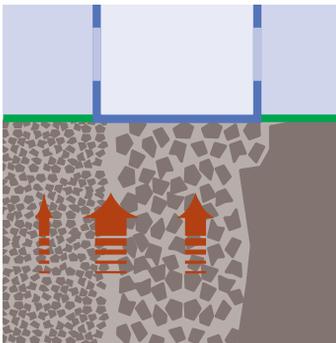
- **Air exchange in the building:**

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 outdoor 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.

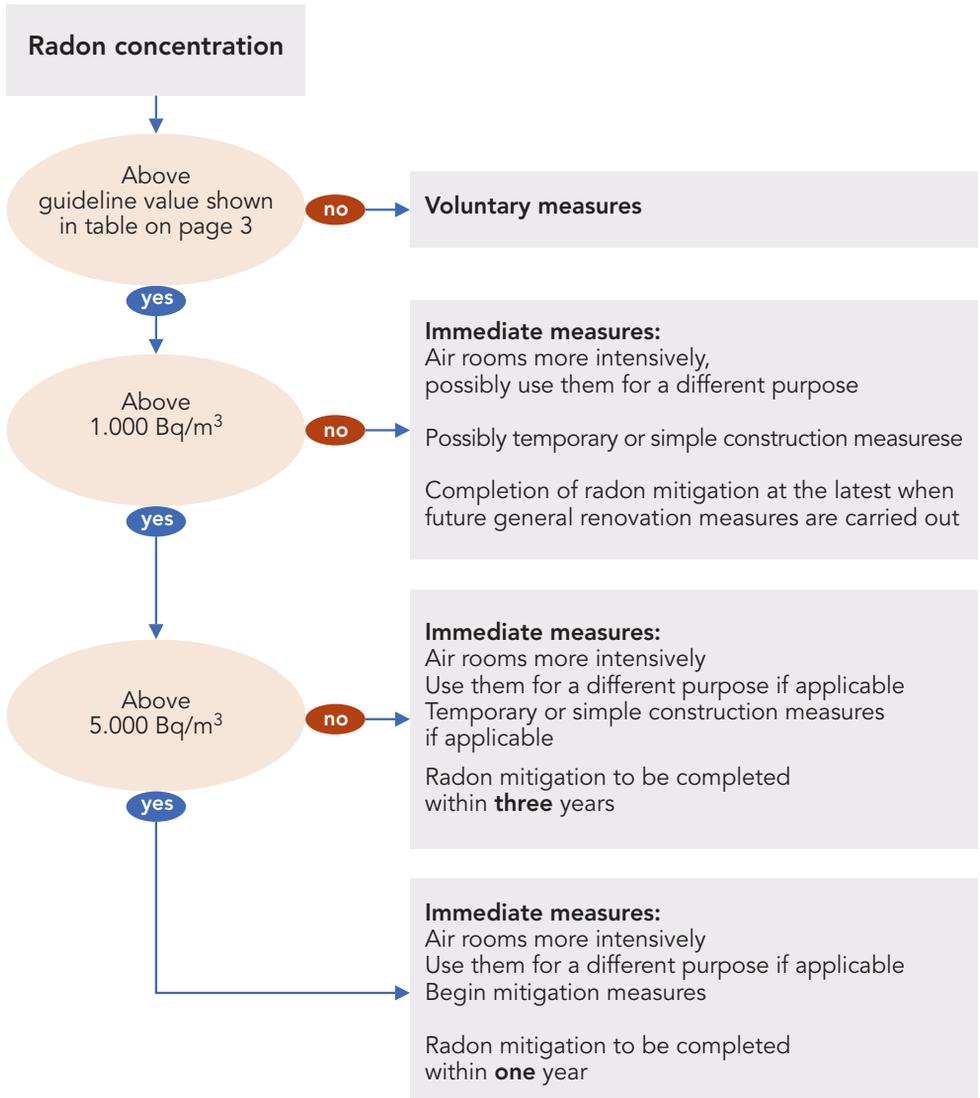


- **Type of ground beneath the building:**

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 Mitigation Measures are Necessary and When?

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



Intensified Airing

Permanent static ventilation of the basement (by leaving windows fully or tilted open) reduces the radon concentration in the basement and thus also in the 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 annual mean radon concentration measured, or airing before using the rooms.

Windows should be left open or tilted as often as possible when the heating system is not in operation.

Note: The radon concentration can return to its previous level within as little as two hours after rooms have been aired.

Converting Affected Rooms

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



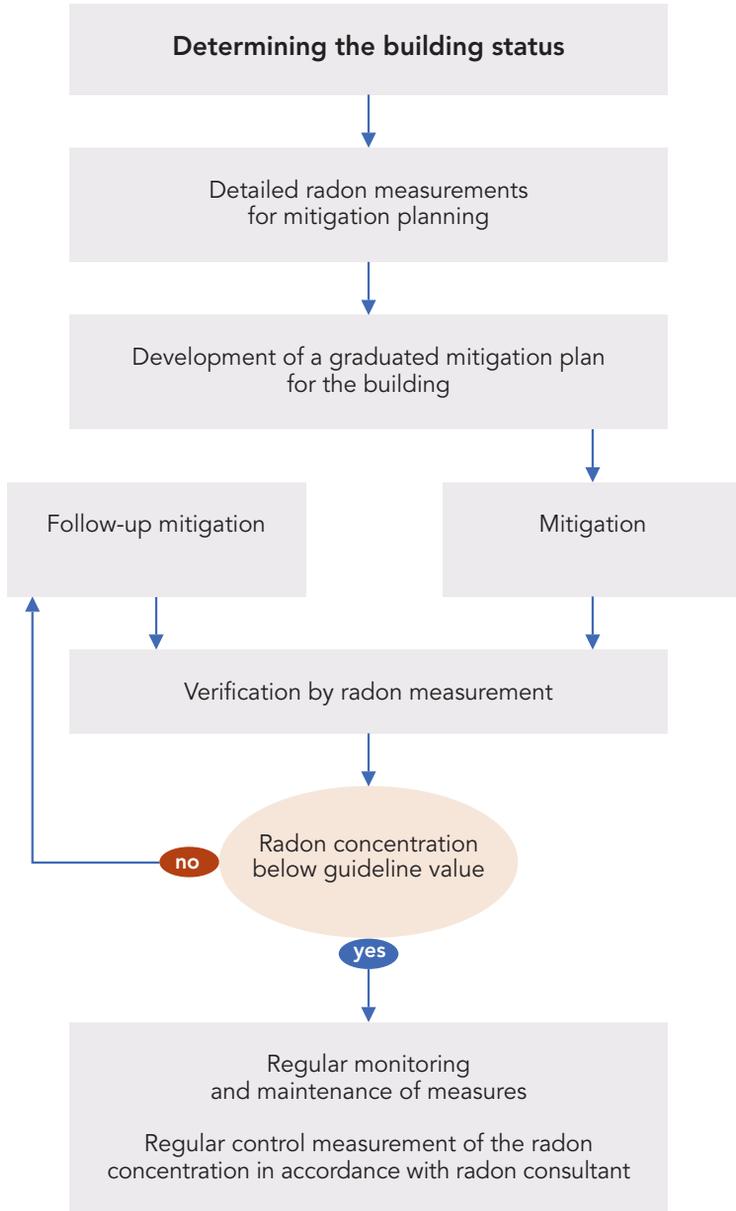
Leaving windows wide open or cross-ventilating for 5 minutes or airing rooms before use reduces the radon concentration



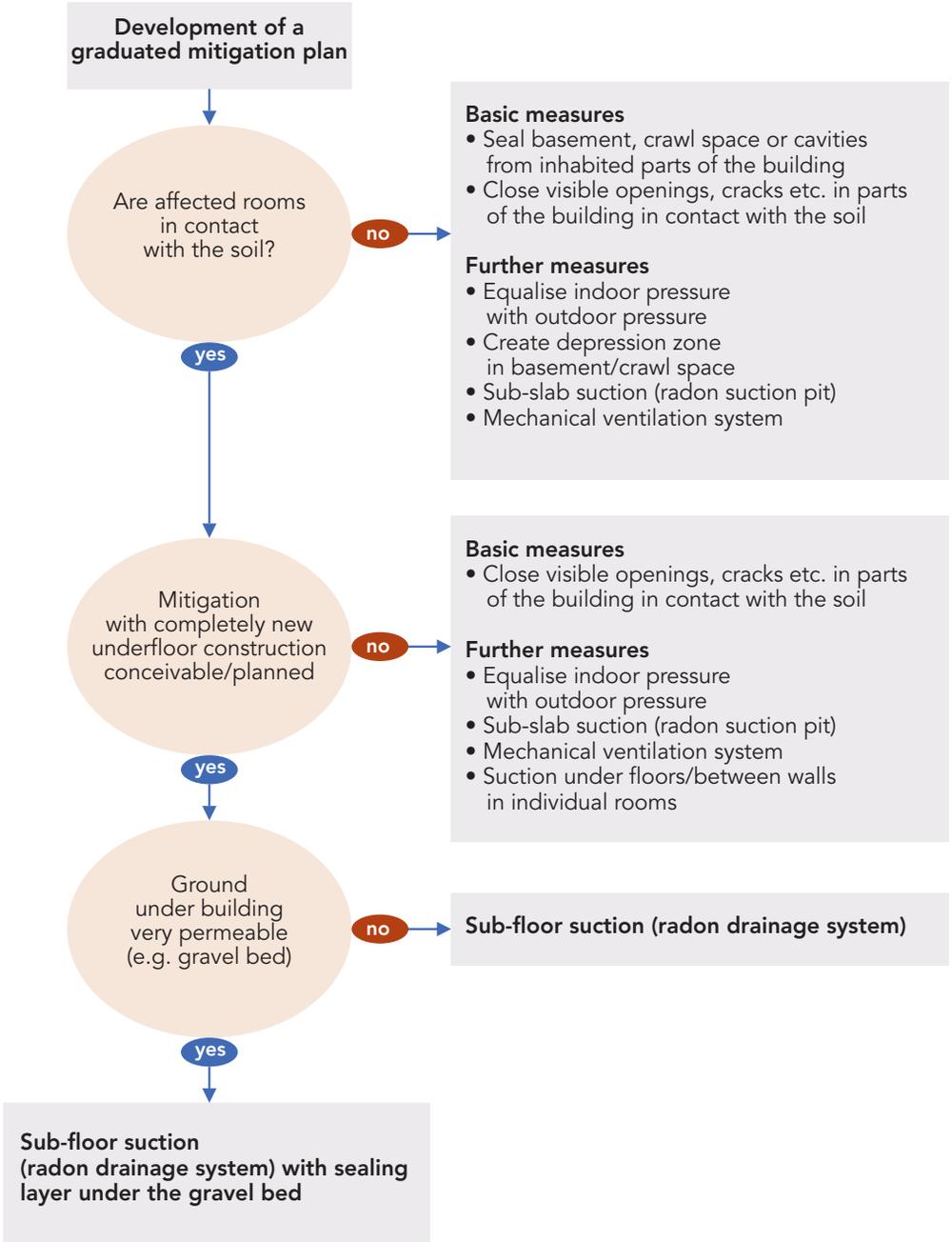
A living room or office can be turned into a room in which people stay only for short periods (e.g. storage room)

Radon Mitigation

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



Graduated Mitigation Plan



Mitigation Methods

The recommended techniques for mitigating buildings with elevated radon levels 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. Sealing as a single measure is normally insufficient.

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

Sealing reduces radon entry 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 natural 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

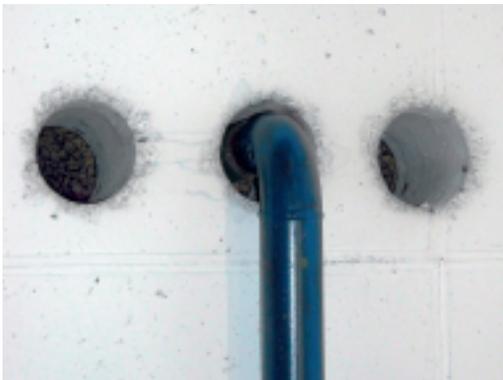
Closing visible openings, cracks etc. in parts of the building in contact with the soil

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

Pressure equalisation indoors/outdoors

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

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



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



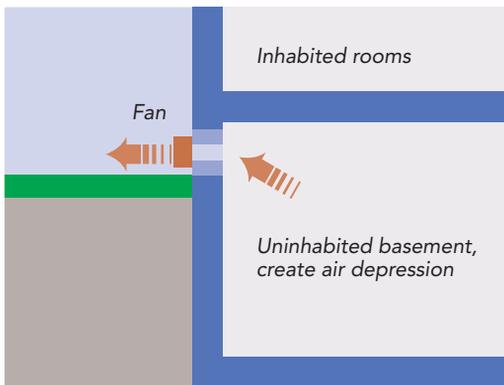
Outside air inlet

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

A small fan creates an air depression in the basement or crawl space, thus reducing radon convection from the basement into the inhabited area.

To create a depression zone, the basement/crawl space must be sealed off from the inhabited area and the outside (windows and doors must be closed).

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



A small fan in the basement creates an air depression with respect to the living space.

Facts and Notes

- Radon is the second leading cause of lung cancer after smoking
- Radon penetrates from the ground into the building through leakages
- National radon risk maps provide initial information
- Only a measurement can give certainty about the radon concentration in a building
- There are simple, established mitigation methods

Sub-floor drainage

The main purpose of this measure is to create a depression zone beneath the foundation slab. This prevents convective entry of radon from the soil into the building.

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

Selective suction (radon suction pit)

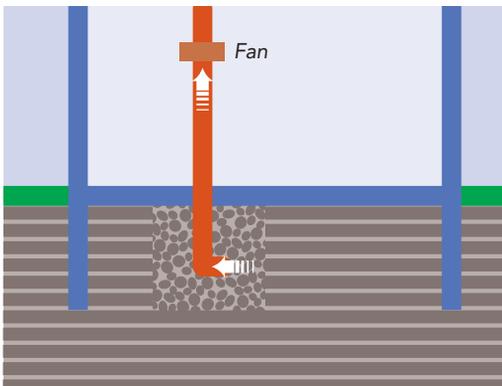
Selective suction can be achieved by:

- using cavities (utility shafts) in contact with the soil underneath the foundation slab
- core drilling through the foundation slab (if there is a gravel 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 drainage system)

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



Selective sub-slab suction vented through the roof



Renewal of the floor: incorporating a radon drainage system

Technical information on constructing a sub-floor drainage system

The vent pipe must be a full-wall pipe with a diameter of at least 7 cm. The pipe either penetrates an external wall horizontally or is 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 depression zone due to the stack effect by using a full-wall pipe with a diameter of 15 cm (the vent pipe must be thermally insulated in the attic). Advantages are the passive creation of a depression and no fan operating costs.

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

Experience proved fans with a power rating of 20–100 W which create a negative pressure of 60–500 Pa to be successful. Fans may be used intermittently (with a timer) if the radon situation permits.

Note on drainage in highly permeable soil:

Where the ground consists of gravel or is heavily eroded (e.g. in karst regions), 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 extract system and the ground must be reduced significantly by a low-cement concrete layer underneath the radon drainage system.



*Selective suction
(radon suction pit) – digging a pit*



*A fan outside the building creates a slight
air depression under the foundation slab.*

Mechanical ventilation system

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

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 find out the air supply rate required to create a slightly positive pressure as well as to test 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 small positive pressure indoors. It should be considered 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 mitigating individual rooms.

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



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

Air intake of a mechanical air supply system

Suction between floors/between walls in individual rooms

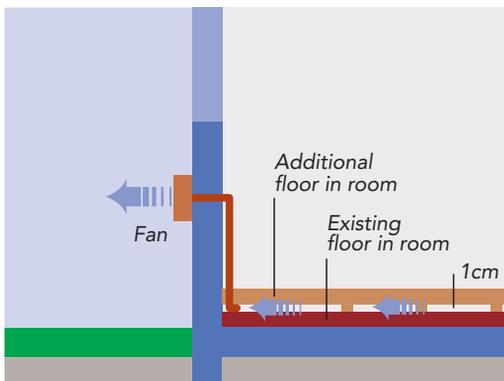
Suction applied between floors in the affected rooms requires the construction of a false floor.

A continuous cavity about 1 cm high needs to be planned between the additional and the original floor in the room. The air of 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 additional floor is well sealed. The adjustment of the fan must be optimised to achieve a minimal air depression.

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

Final Remarks

- In rare instances, radon mitigation methods involving an air depression 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.



Between-floors suction in a single room

**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*

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*)

AGES - Austrian Agency for Health and Food Safety, Austrian Centre for Radon

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