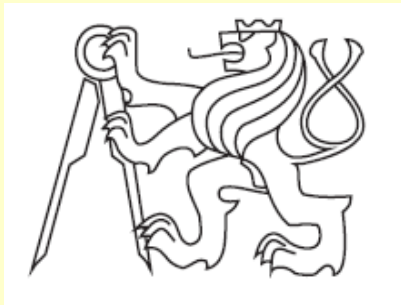


RADON PREVENTIVE AND REMEDIAL MEASURES IN THE CZECH REPUBLIC

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History of radon prevention in the Czech Republic

- Realization of preventive measures became obligatory in 1991 by the degree of Ministry of Health
- Since 1991 each building built on a building site with medium or high radon index must be protected against radon from the soil
- We estimate that approx. 2/3 of new buildings require protection, i.e. 12.000 each year
- Since 1991 the preventive measures were realized in approx. 200.000 buildings

Documentation supporting the design

Principles of designing and application of various types of radon reduction techniques are presented in the following standards:

- **ČSN 73 0601** Protection of buildings against radon from the soil, 1995, 2000, 2006
- **ČSN 73 0602** Protection of buildings against radon and gamma radiation from building materials, 2000, 2006
- **Radon – Building Context** – detailed manual for building professionals

PRINCIPLES OF PROTECTION

The type and the degree of protection depends on the “**radon index**” of the building site (low, medium, high).

Radon index	Principle of protection
Low	No special protection is required.
Medium	The basic measure is a radon-proof insulation .
High	Radon-proof insulation is usually combined with: <ul style="list-style-type: none">• sub-slab depressurization• air gaps ventilation• mechanical ventilation of indoor air

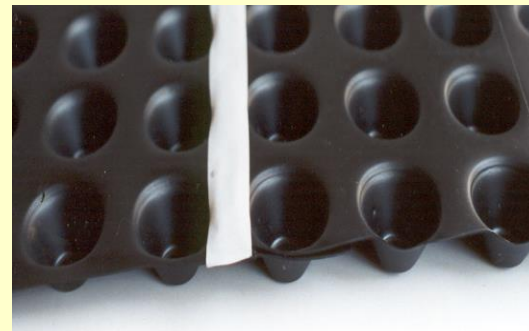
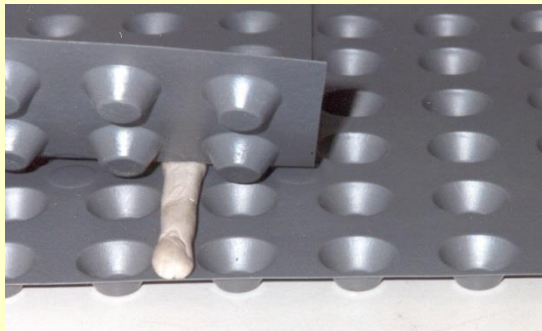
Radon-proof insulation

Radon-proof insulation is selected from standard waterproofing materials.

- **radon diffusion coefficient** of the insulation must be measured
- **durability** must correspond to the lifetime of the building

Prohibited materials

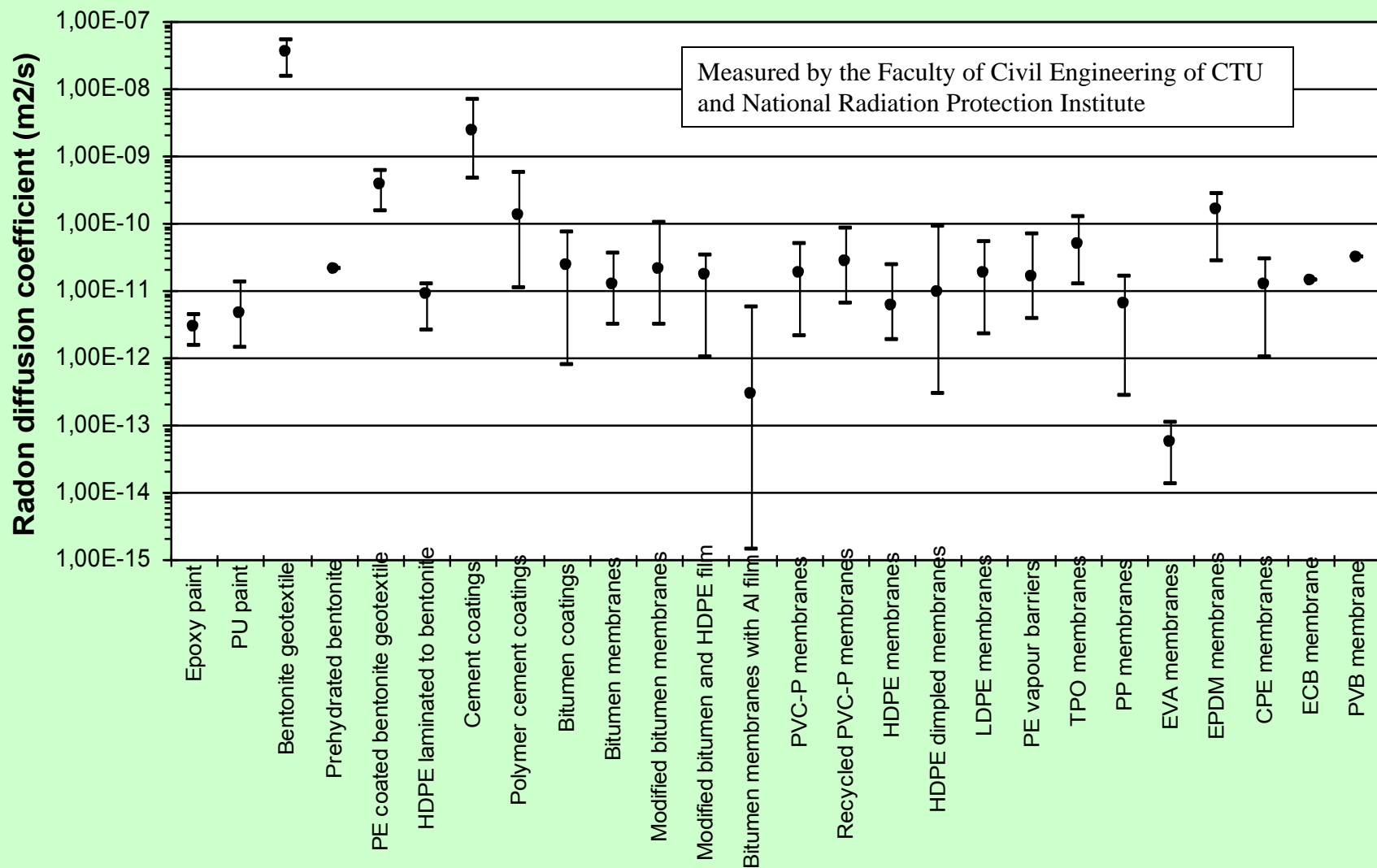
Bitumen membranes with Al foil and plastic membranes with dimples (Delta, Platon, Tefond, etc.)



Determination of the Rn diffusion coefficient

- Systematic testing started in 1995 according to the method developed by the Faculty of Civil Engineering in cooperation with the National Radiation Protection Institute
- The Czech test method is accredited by the Czech Accreditation Institute
- Up to now more than 400 materials obtained throughout Europe have been tested
- The tests of radon diffusion coefficient are required by the Czech technical standard ČSN 73 0601 „Protection of buildings against radon from the soil“

Summary of radon diffusion coefficient measurements



Application of the radon diffusion coefficient for the design of radon barriers

1. Limit for the maximal value of D

Applied for example in Ireland ($\max D = 12 \cdot 10^{-12} \text{ m}^2/\text{s}$)

2. Limit for the minimal thickness of the membrane

Applied for example in Germany ($d \geq 3l$)

3. Calculation of the membrane thickness in dependence on the soil and building characteristics

Applied for example in Czech Republic

Thickness of the radon-proof insulation

$$d \geq l \cdot \operatorname{arcsinh} \frac{\alpha_1 \cdot l \cdot \lambda \cdot C_s \cdot (A_f + A_w)}{C_{dif} \cdot n \cdot V}$$

C_s ...radon concentration in the soil gas (Bq/m³)

λ radon decay constant (0,00756 h⁻¹)

d thickness of the membrane (m)

l radon diffusion length in the membrane $l = (D/\lambda)^{1/2}$ (m)

D radon diffusion coefficient in the membrane (m²/h)

α_1 ...safety factor

$A_f A_w$.floor and wall areas in contact with the soil (m²)

nventilation rate (h⁻¹)

C_{dif} ...fraction of reference level caused by diffusion (Bq/m³)

Verification of the air-tightness of joints by the radon diffusion coefficient

SBS modified bitumen membrane	$(7,1 \pm 0,2) \cdot 10^{-12}$
Overlap joint sealed by torching	$(8,6 \pm 1,0) \cdot 10^{-12}$
Self-adhesive overlap joint	$1,2 \cdot 10^{-8} - 1,7 \cdot 10^{-11}$



Joints of self-adhesive membranes should be sealed by torching.

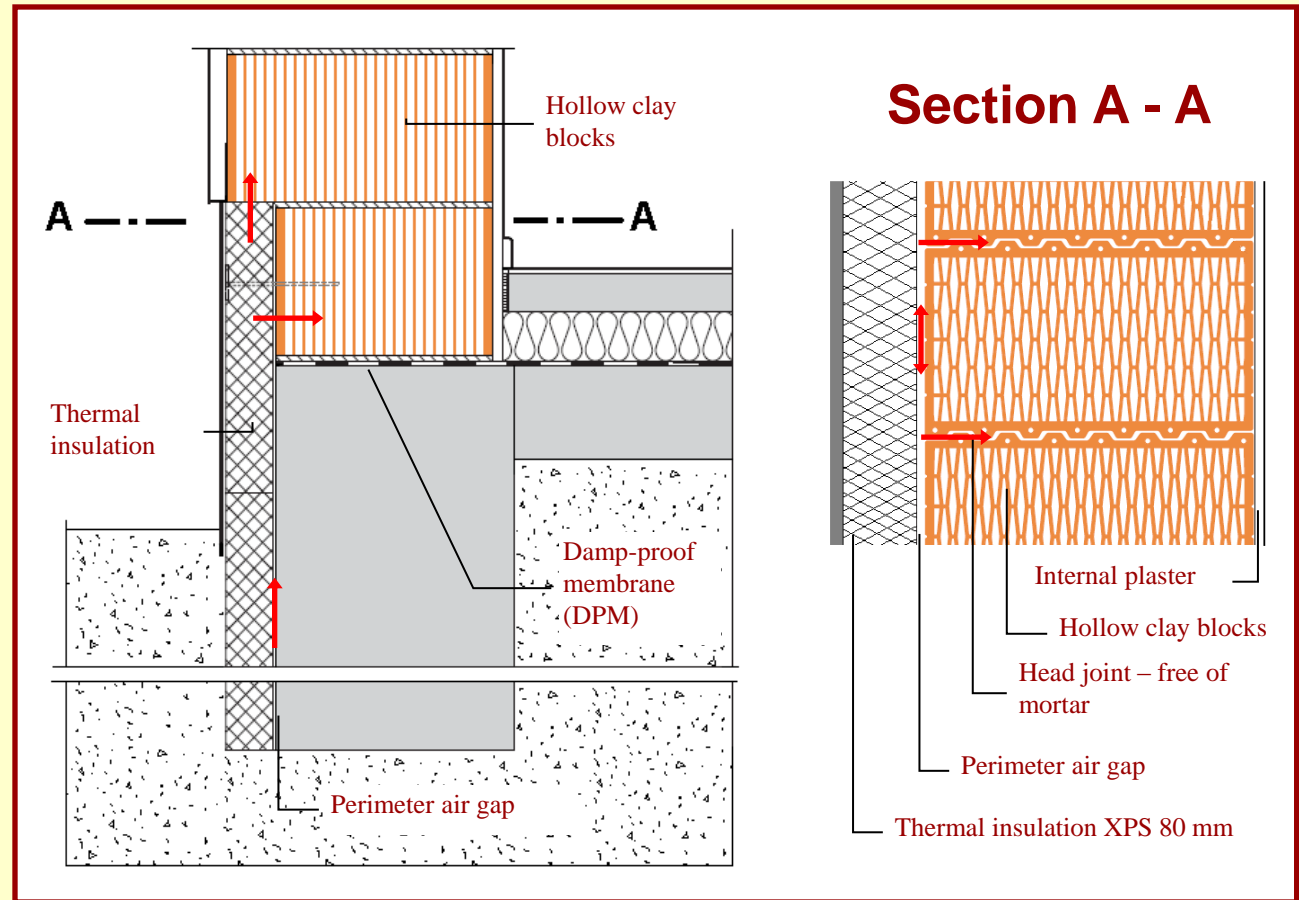
HDPE dimpled membrane	$(4,1 \pm 0,1) \cdot 10^{-12}$
Overlap joint sealed by self adhesive tape	$(7,4 \pm 0,7) \cdot 10^{-10}$

According to CSN 73 0601 it is not permitted to apply dimpled membranes for radon barriers.

Thermal protection X radon protection

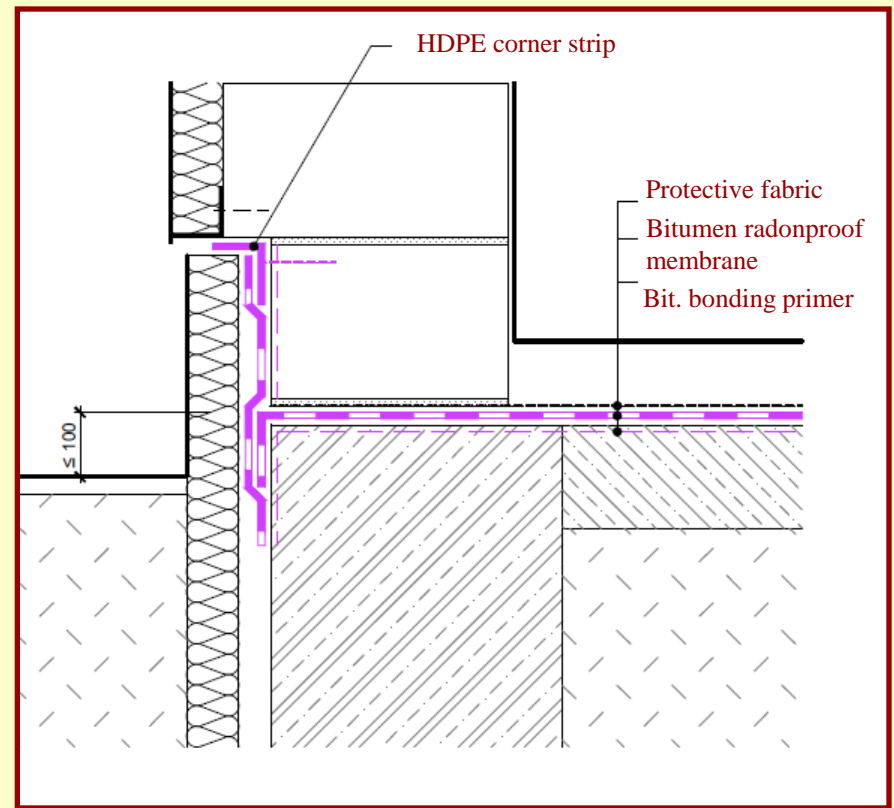
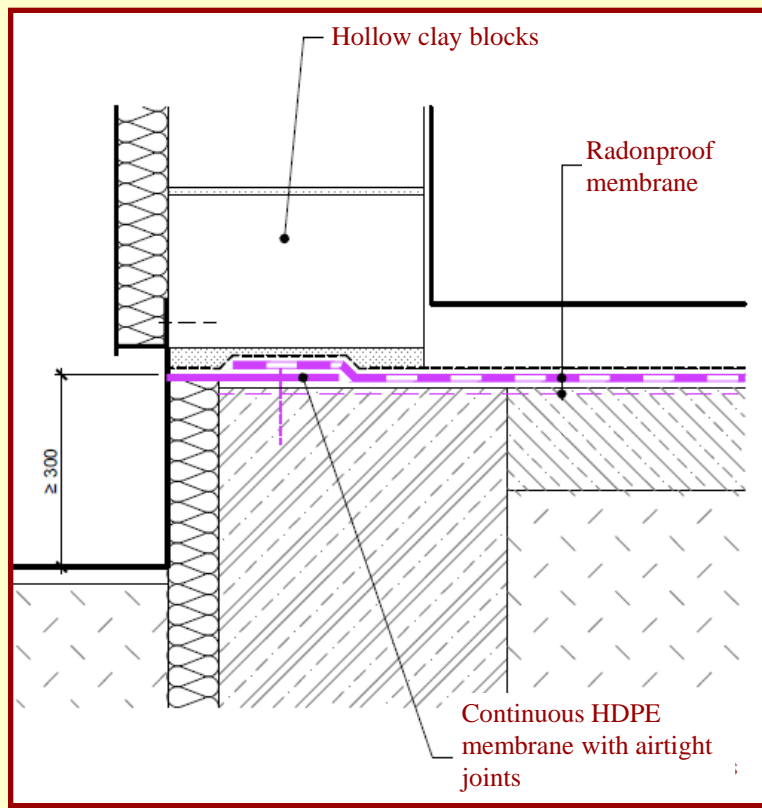
Radon-proof insulation must prevent radon from penetrating through an air gap between perimeter thermal insulation and foundations

Elimination
of thermal
bridges
should not
result in
radon
bridges



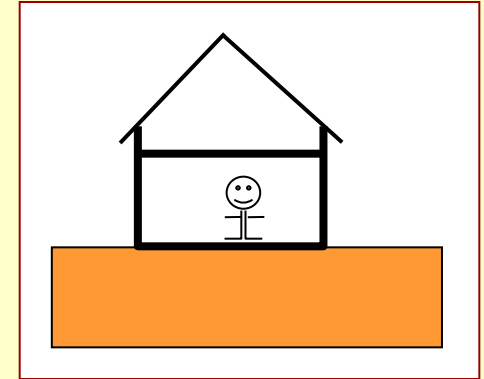
Eliminating radon bridges

Interrupting an air gap between perimeter thermal insulation and foundations



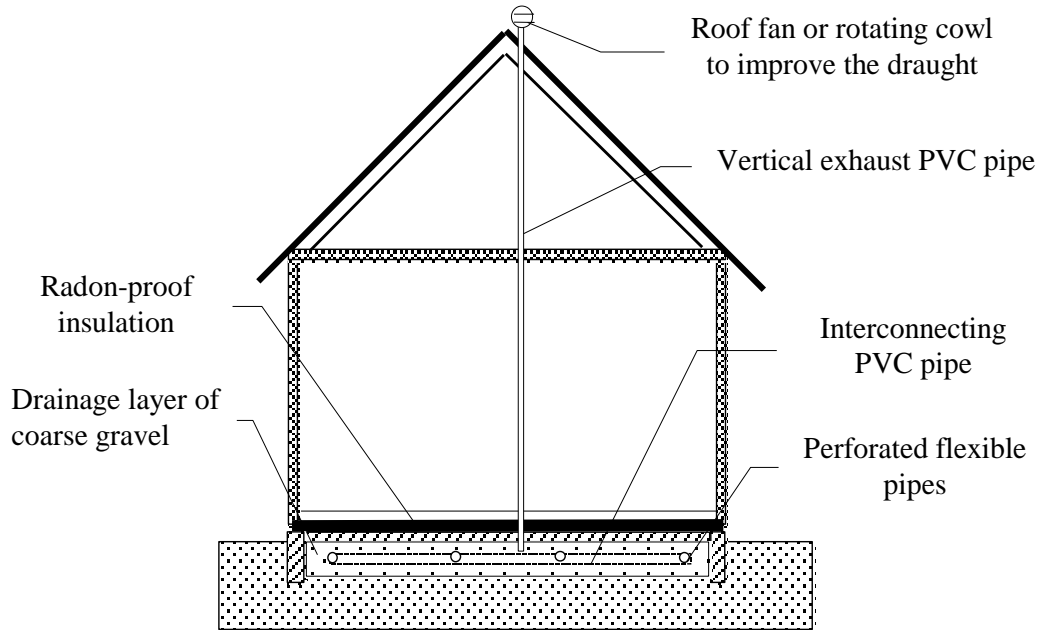
Combined systems

Combined systems are applied in houses with habitable rooms on the floors in direct contact with the soil, when:



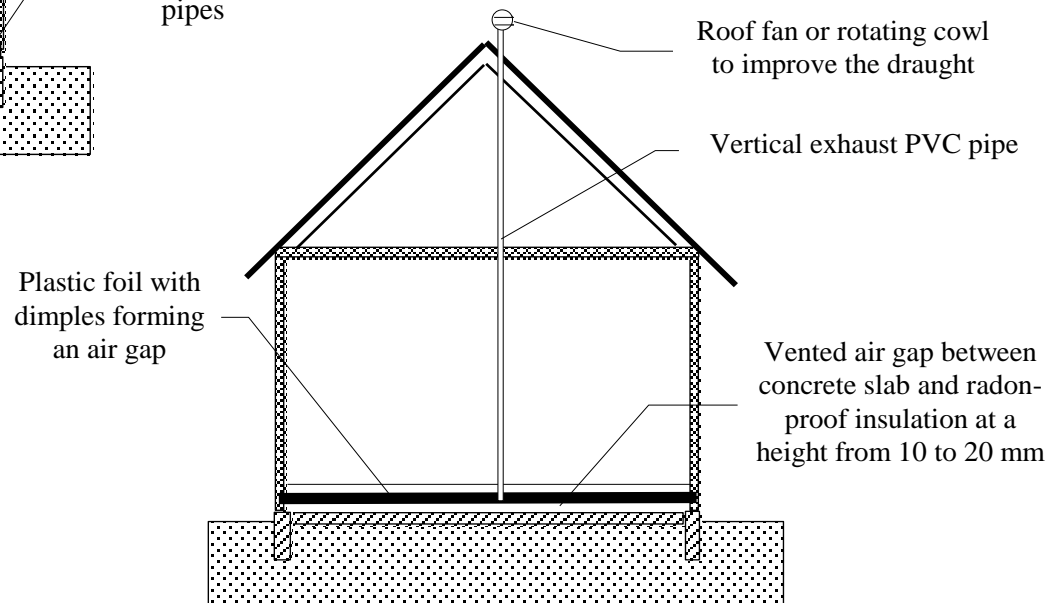
- Highly permeable gravel layer is placed under the house
- Floors resting on the soil are equipped with under-floor heating
- Radon index of foundation soils is high

Combined systems



**Radon-proof insulation
+ sub-slab ventilation**

**Radon-proof insulation
+ air gaps ventilation**



Sub-slab ventilation systems



Drainage layer

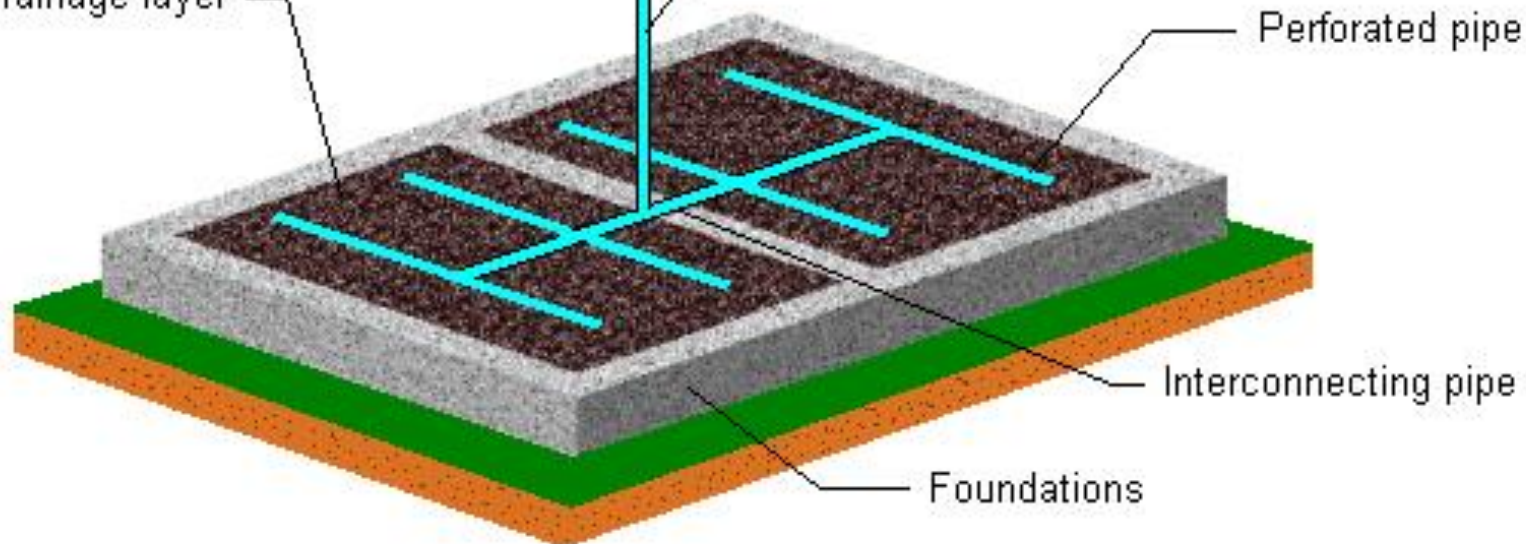


Roof fan or rotating cowl

Vertical exhaust pipe



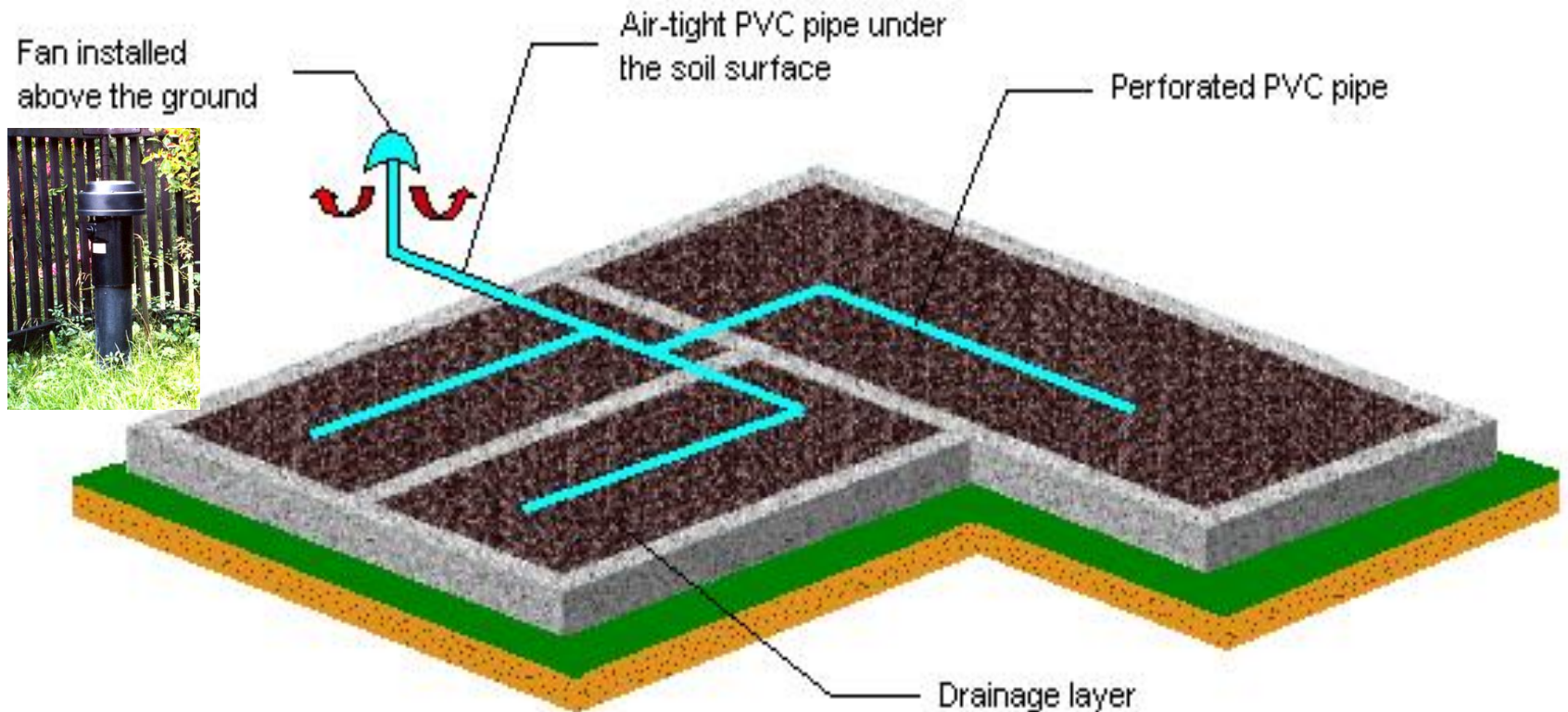
Perforated pipe



Interconnecting pipe

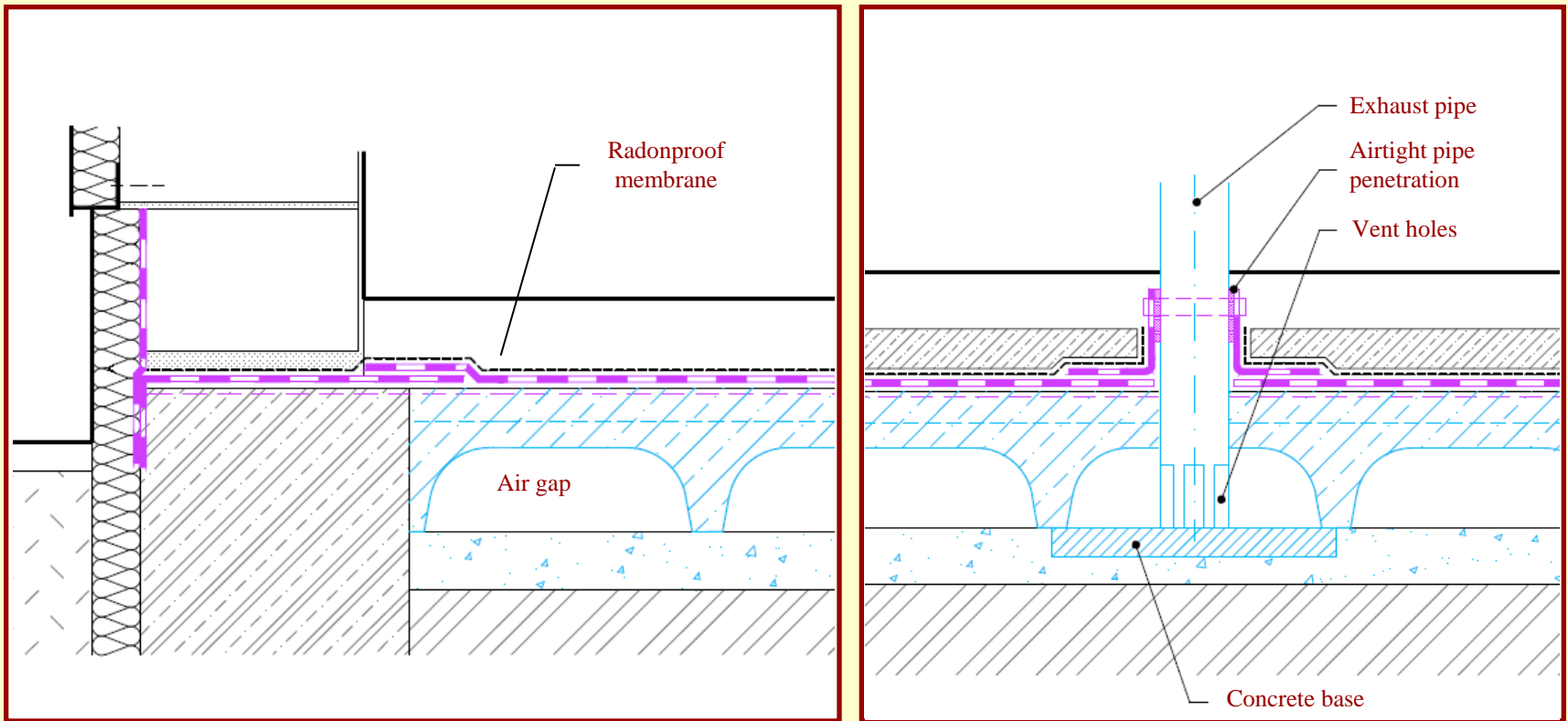
Foundations

Geometry of sub-slab ventilation systems



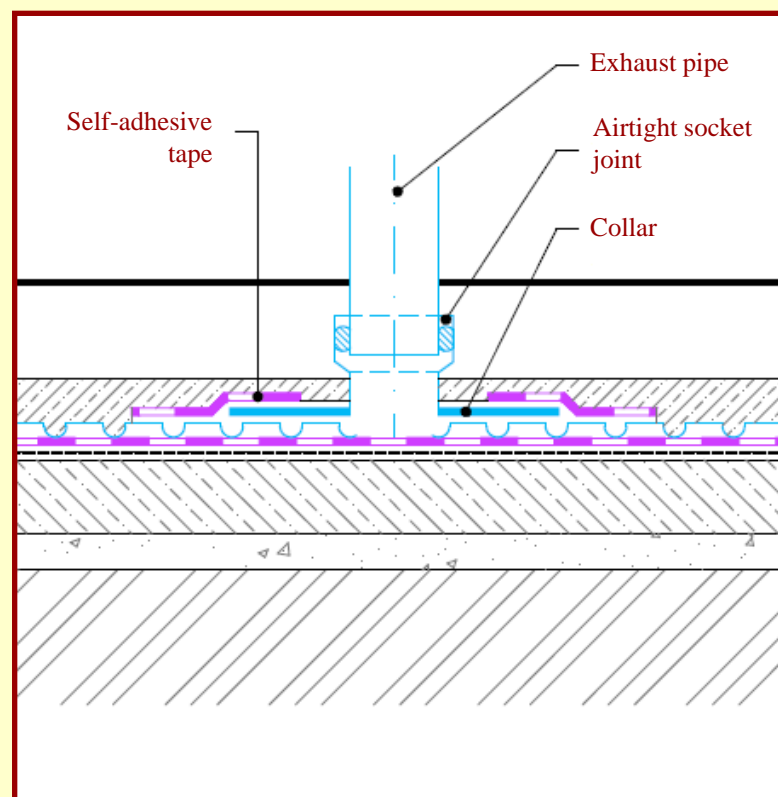
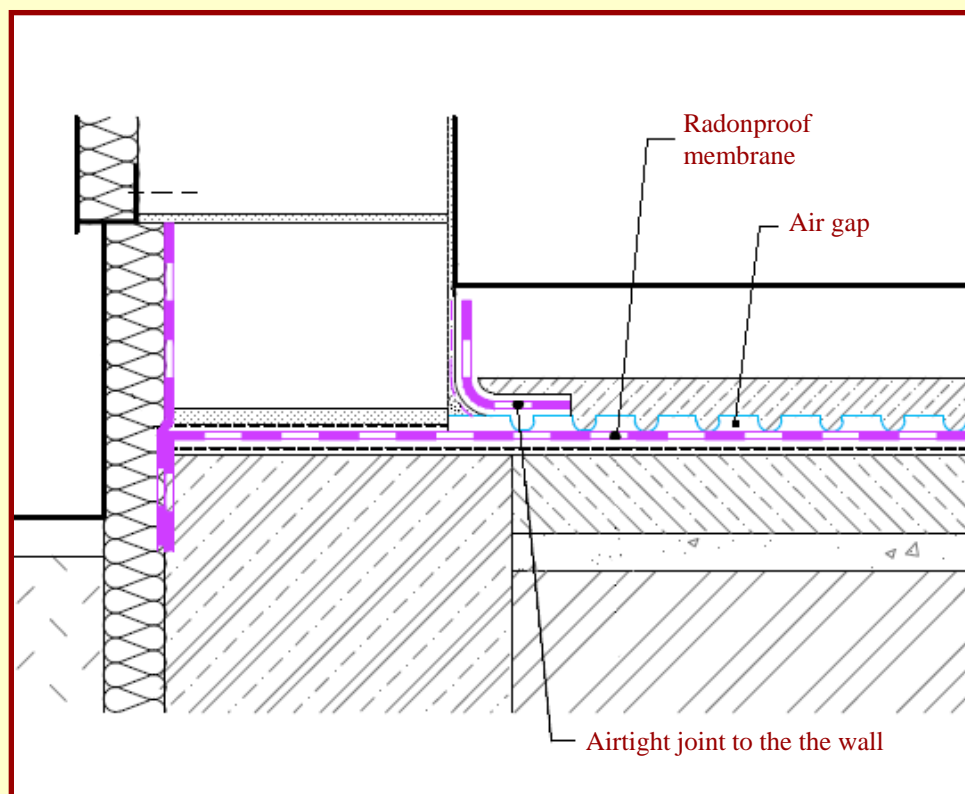
Floor air gaps ventilation

An air gap below the radon-proof membrane



Floor air gaps ventilation

An air gap above the radon-proof membrane



REMEDIATION OF EXISTING BUILDINGS

The type and the degree of remedial works depend on the **level of indoor radon concentration** and results of **diagnostic measurements** performed in the building.

Indoor radon concentration $< 600 \text{ Bq/m}^3$

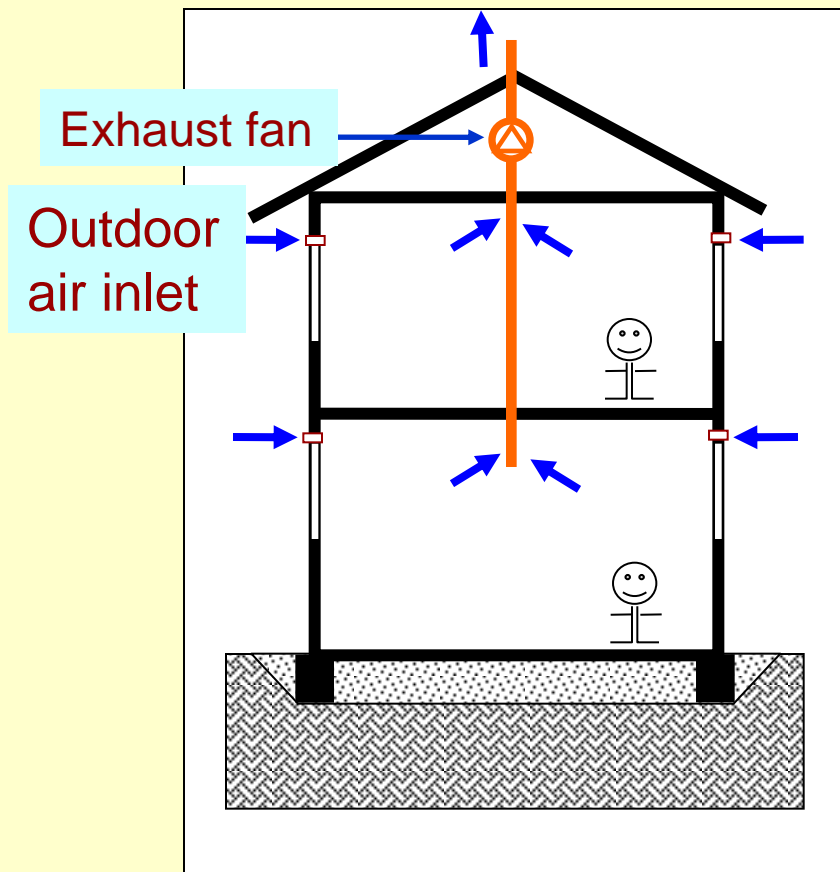
Simple methods (sealing of entry routes, improving ventilation, etc.)

Indoor radon concentration $> 600 \text{ Bq/m}^3$

More effective methods (sub-slab depressurization, replacement of existing floors, mechanical supply and exhaust air ventilation)

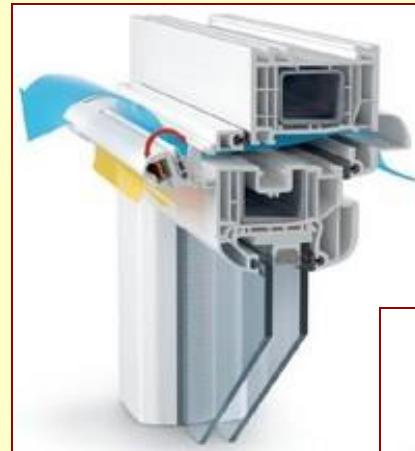
Improving ventilation

- Natural ventilation supported by outdoor air inlets
- Mechanical exhaust air ventilation with outdoor air inlets



Types of outdoor air inlets

Window registers



Wall registers



Improving ventilation

Mechanical supply and exhaust air ventilation - local ventilation units with heat recovery



Typical characteristics:

Power: 4 – 25 W

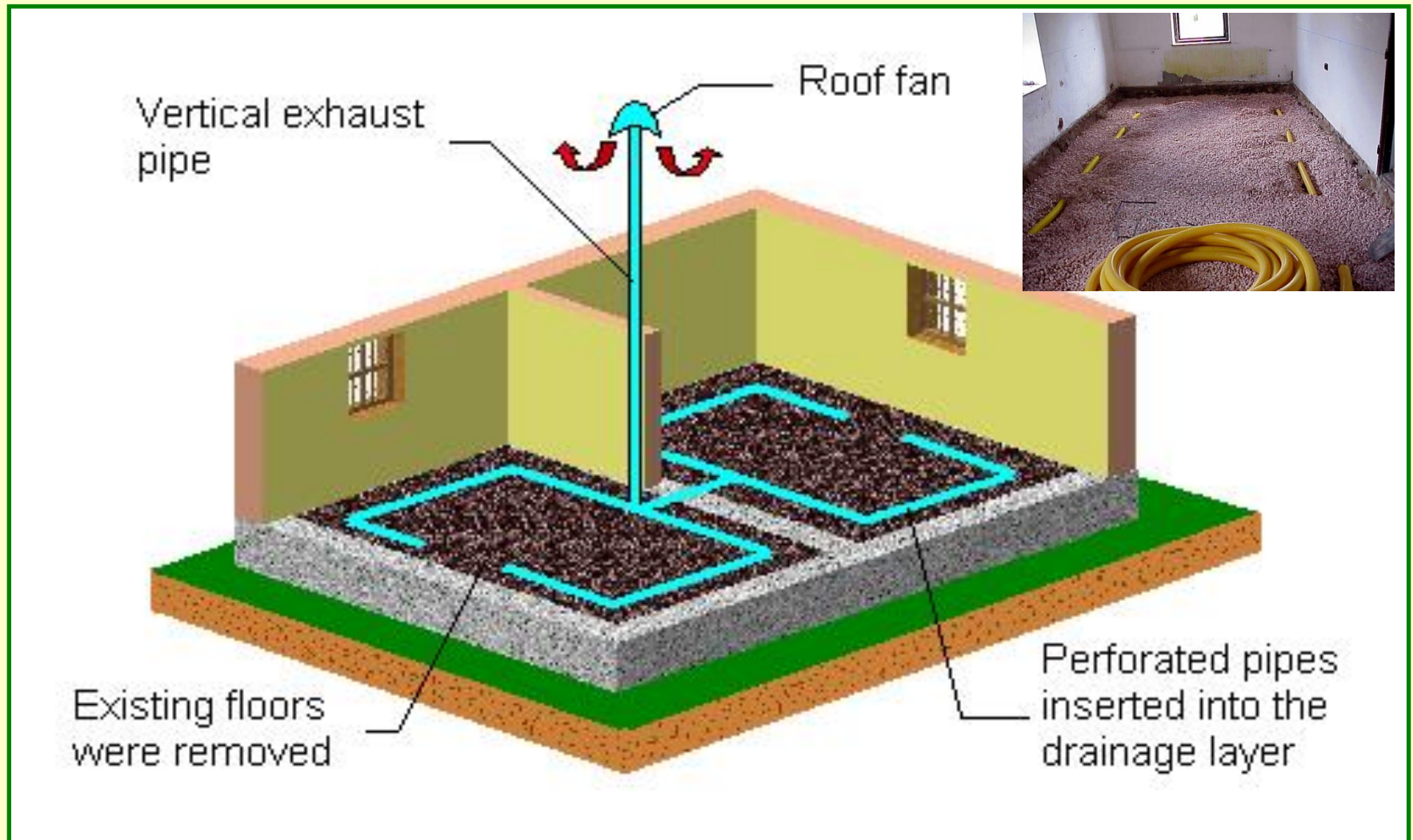
Air flow: 15 – 60 m³/h

Noise level: 17 – 49 dB(A)

Efficiency of heat recovery: < 75 %

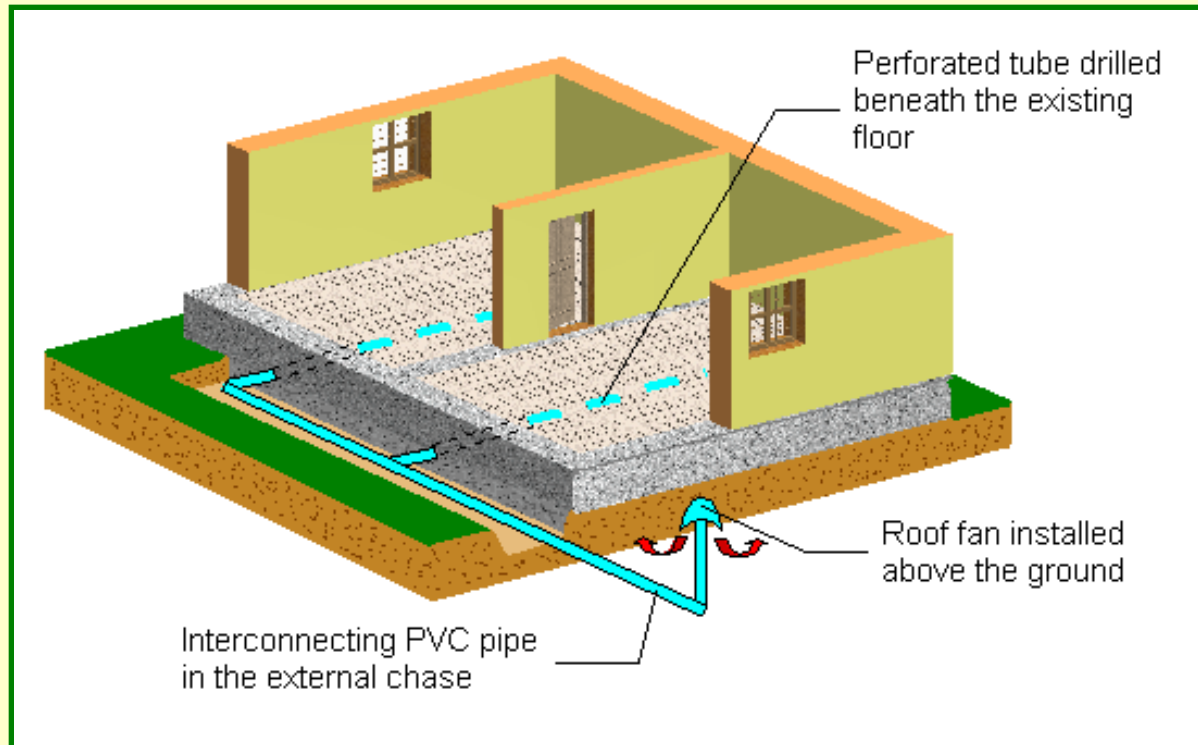
Intended for application in particular rooms with the floor area < 45 m².

Network of flexible perforated pipes inserted into the drainage layer





Perforated tubes drilled from the external trench



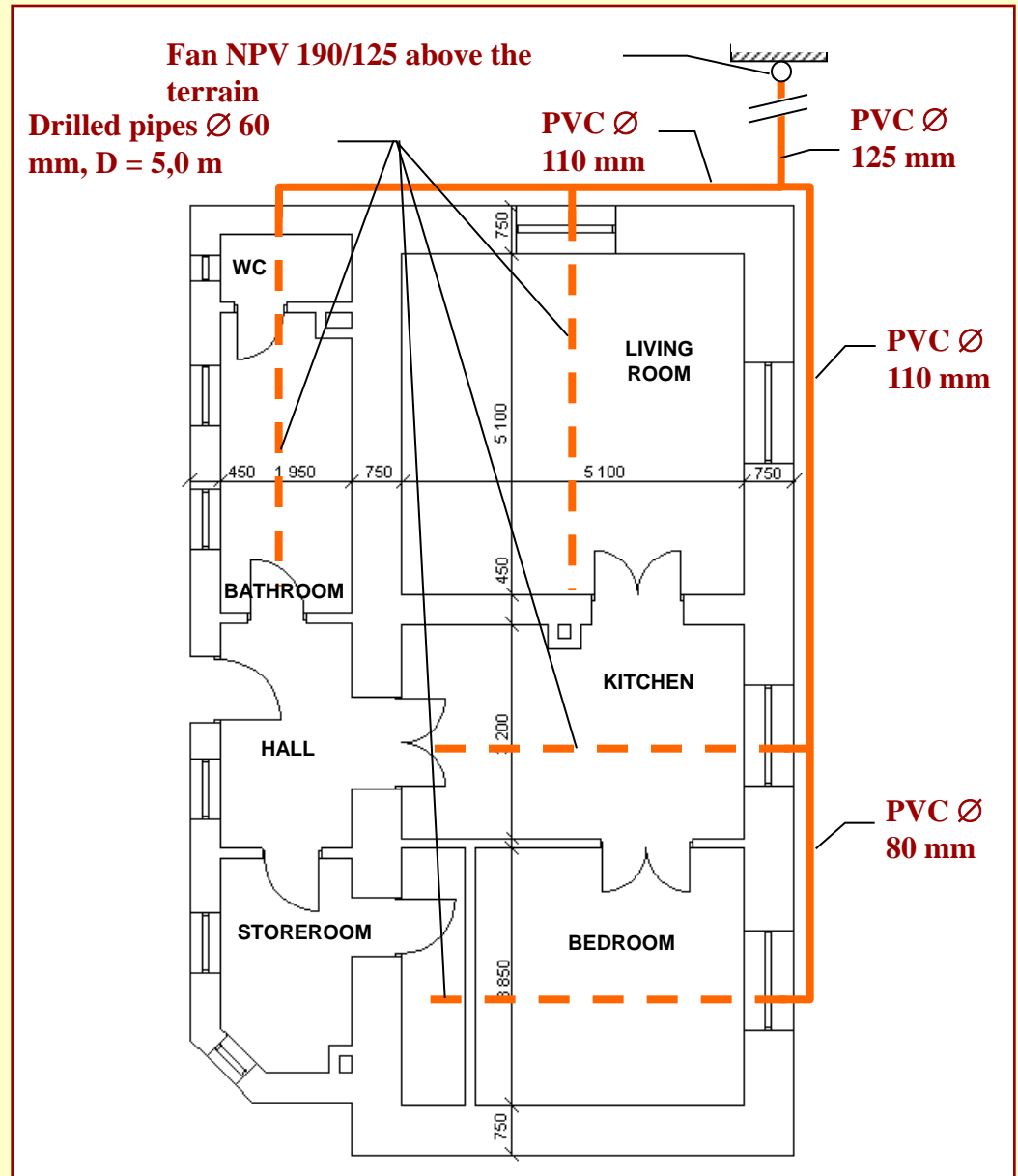
Example of application

Single family house

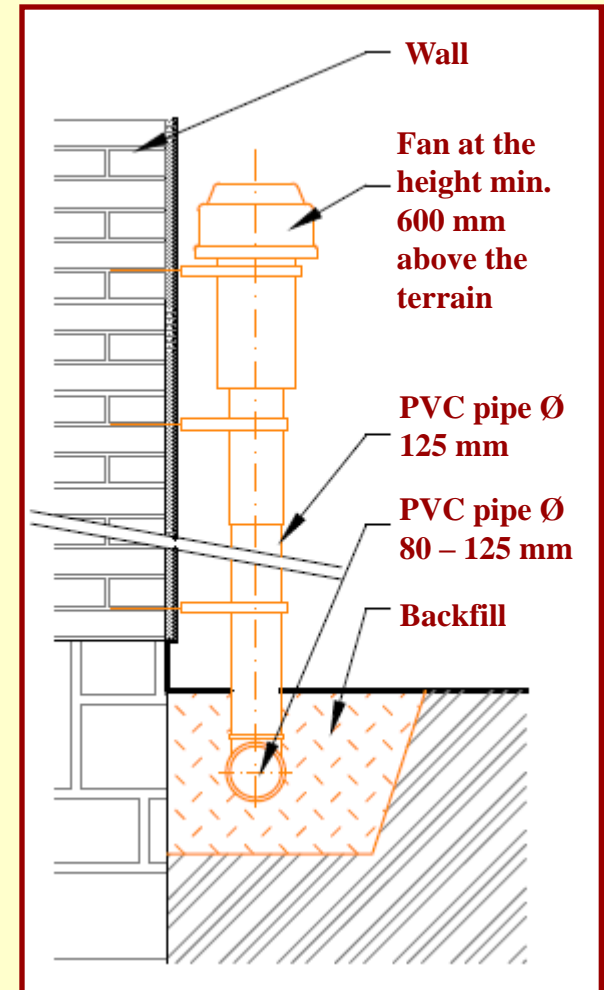
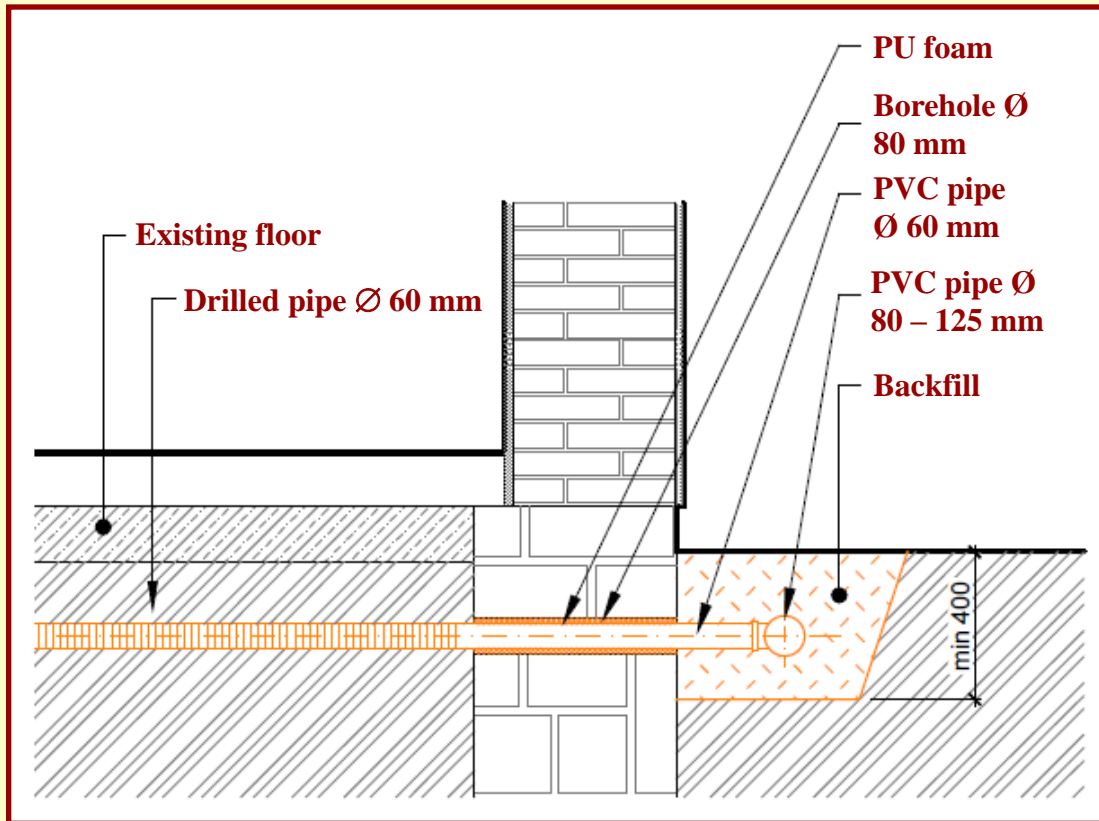


Indoor radon
concentration before
mitigation:

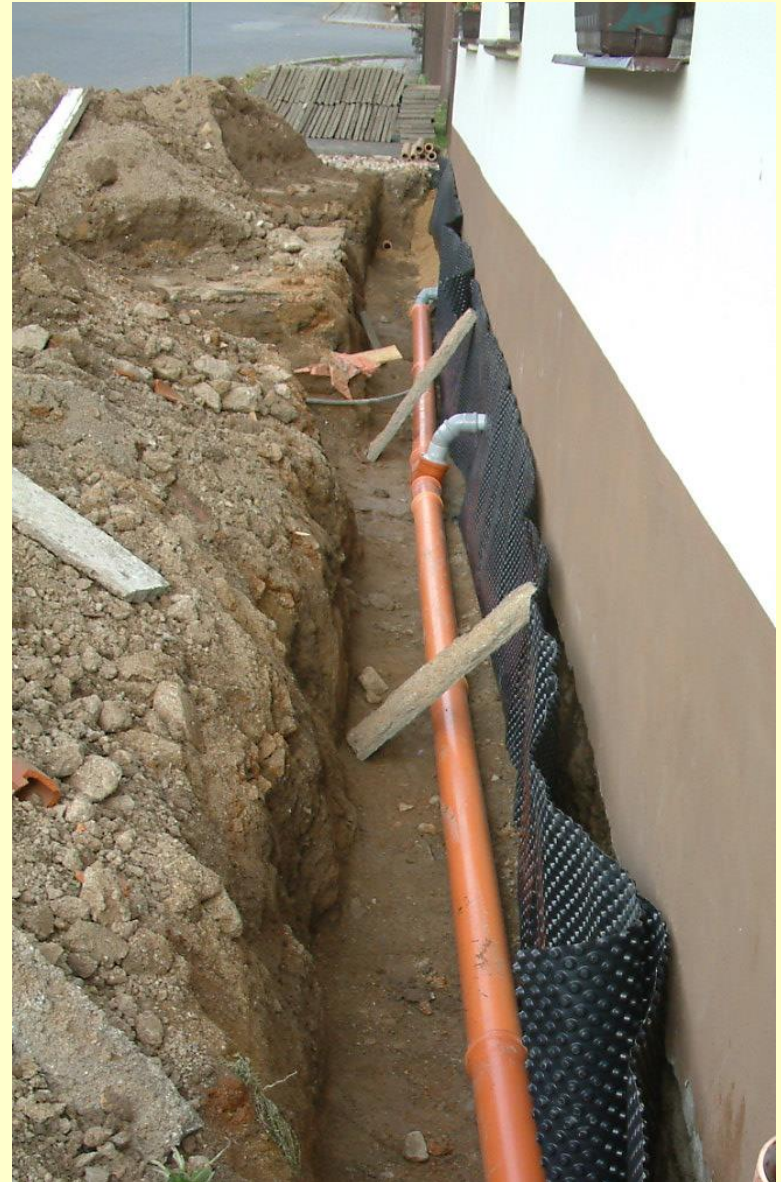
1 145 Bq/m³



Details of remedial measures

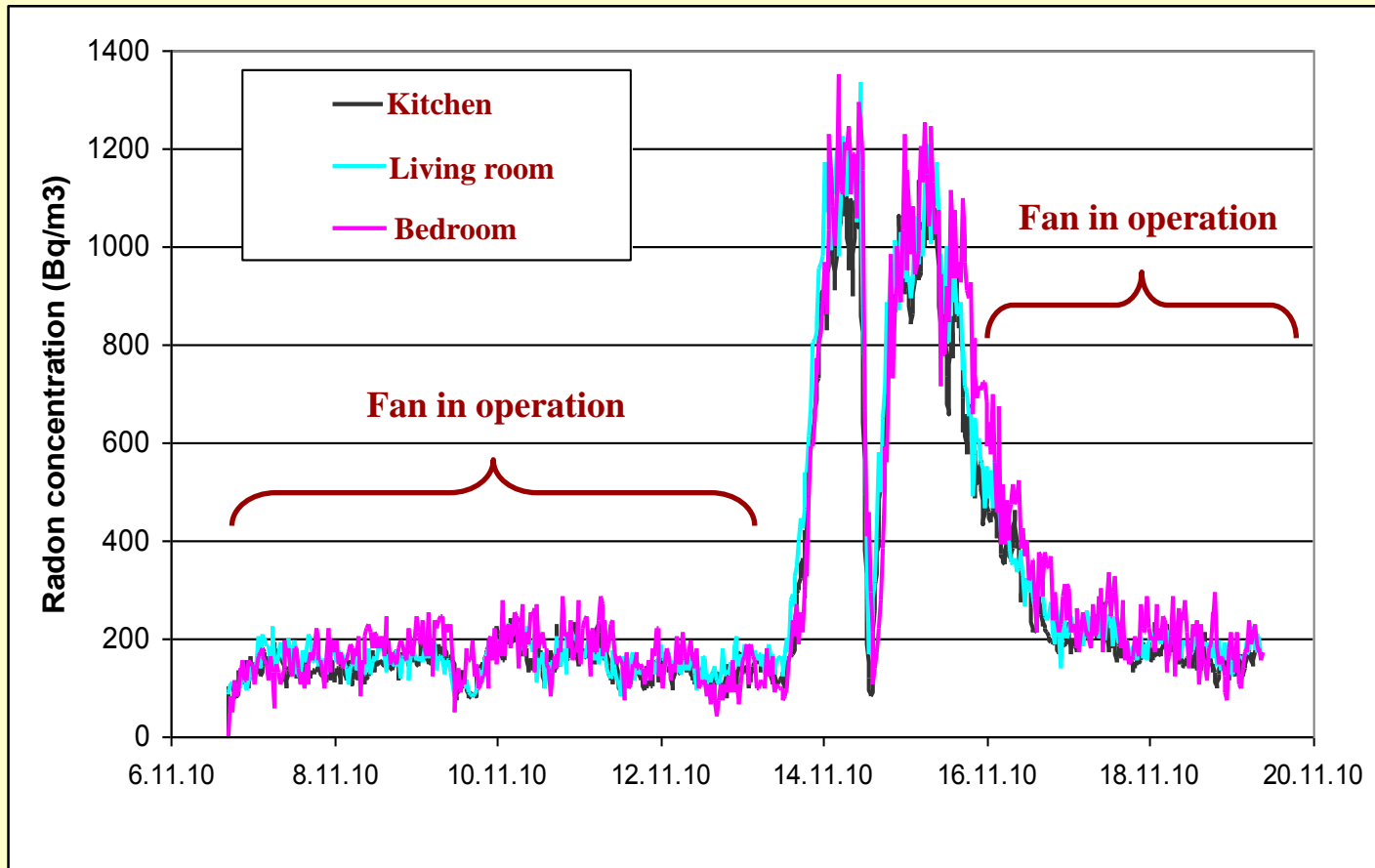


Details of remedial measures

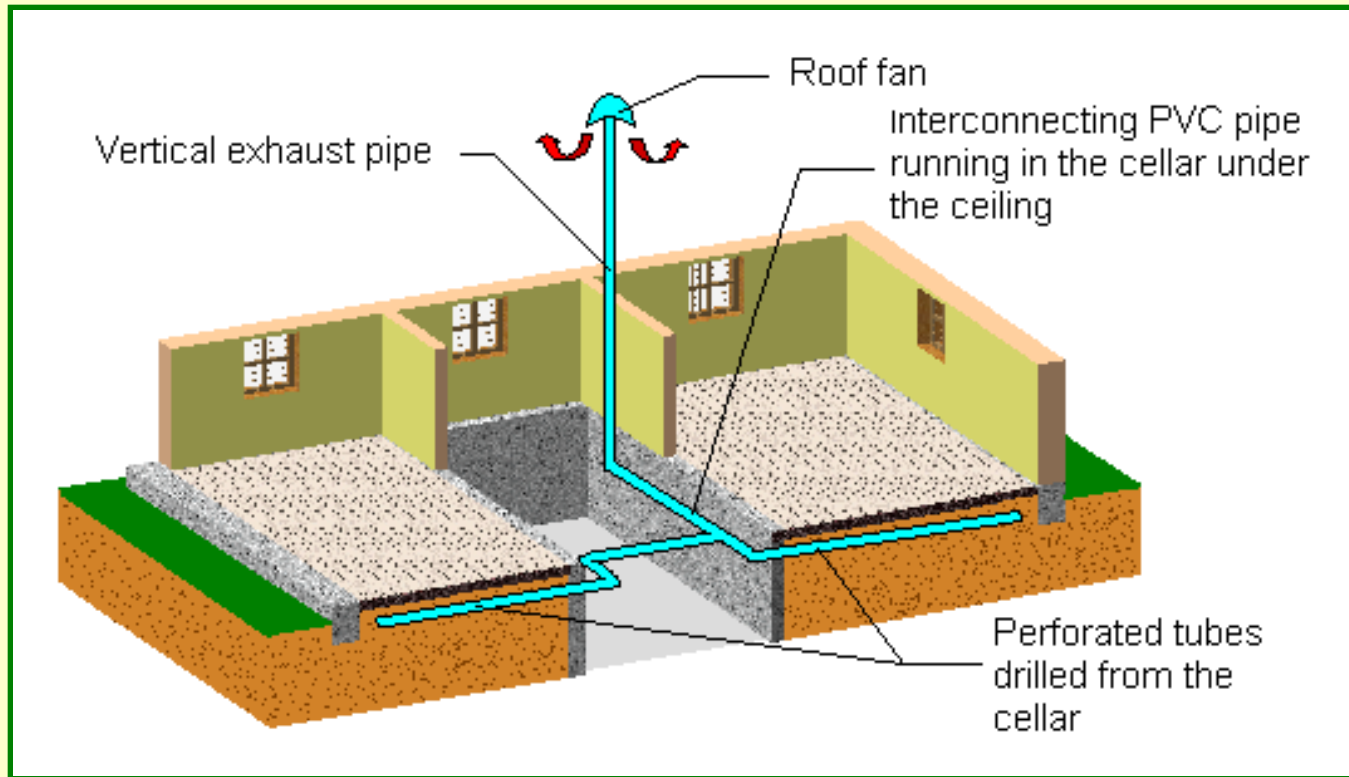


Indoor radon concentration after remediation

During active ventilation indoor radon concentration decreased to the mean value 152 Bq/m³.



Perforated tubes drilled from the cellar

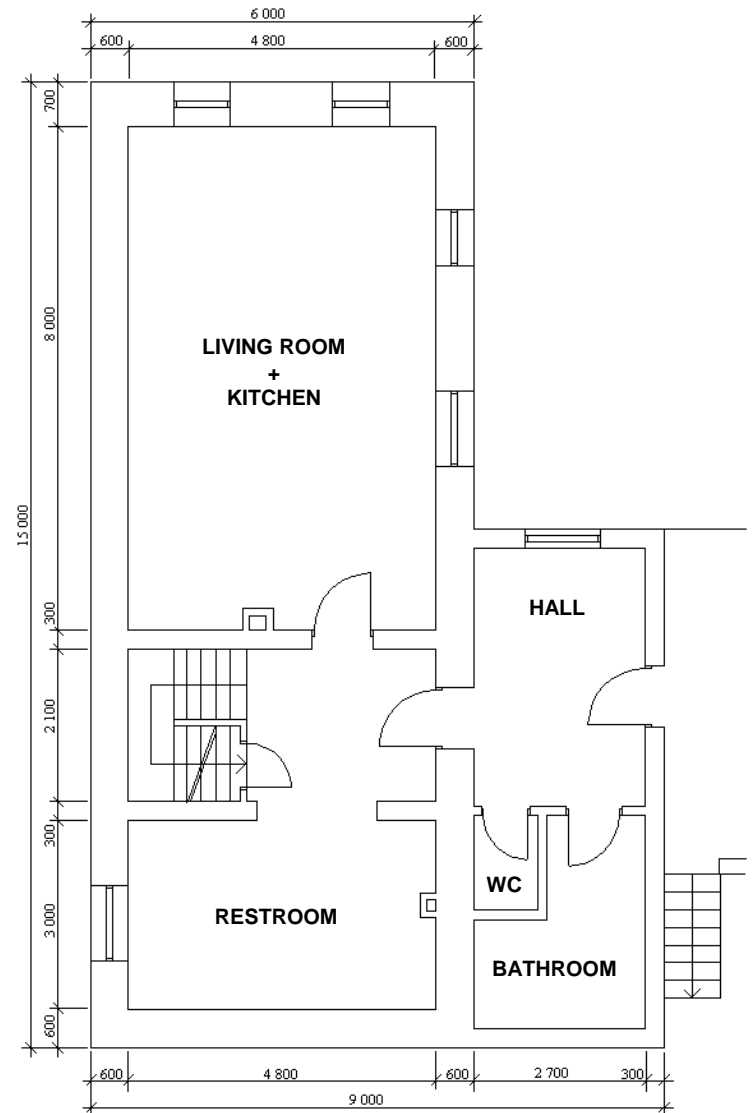


Example of application

Single family house



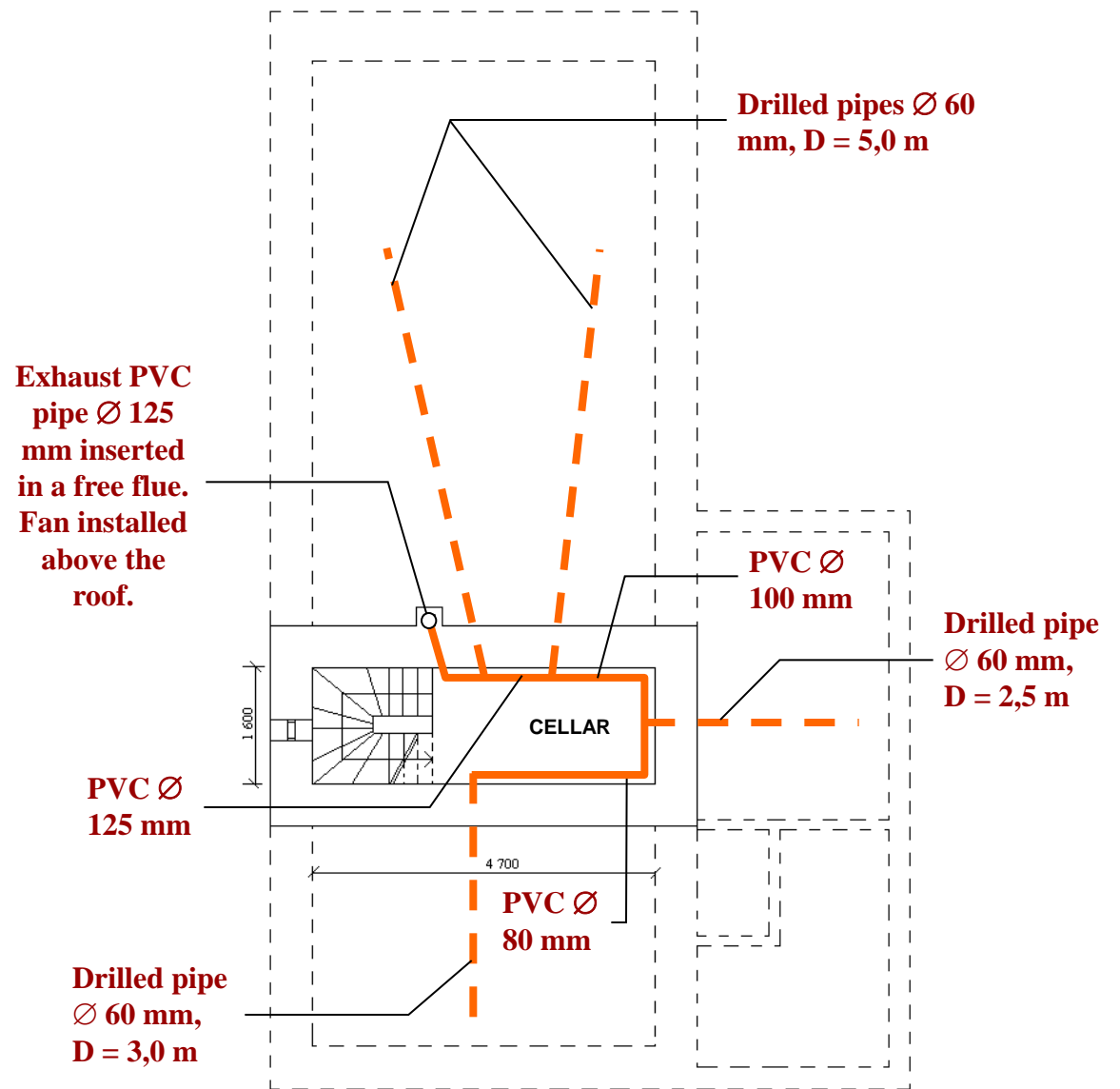
**Indoor radon
concentration before
mitigation:
3 240 Bq/m³**



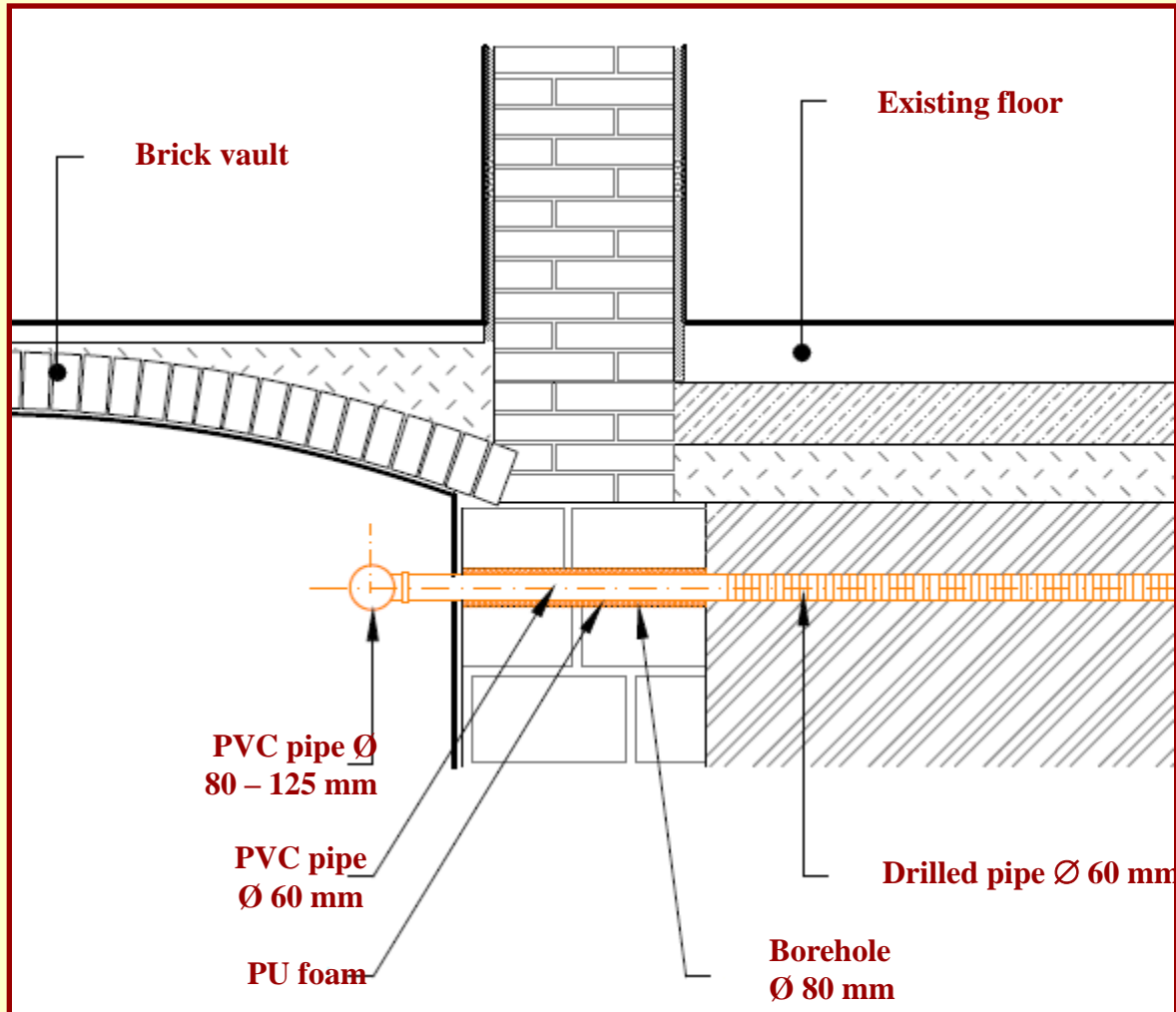
Details of remedial measures



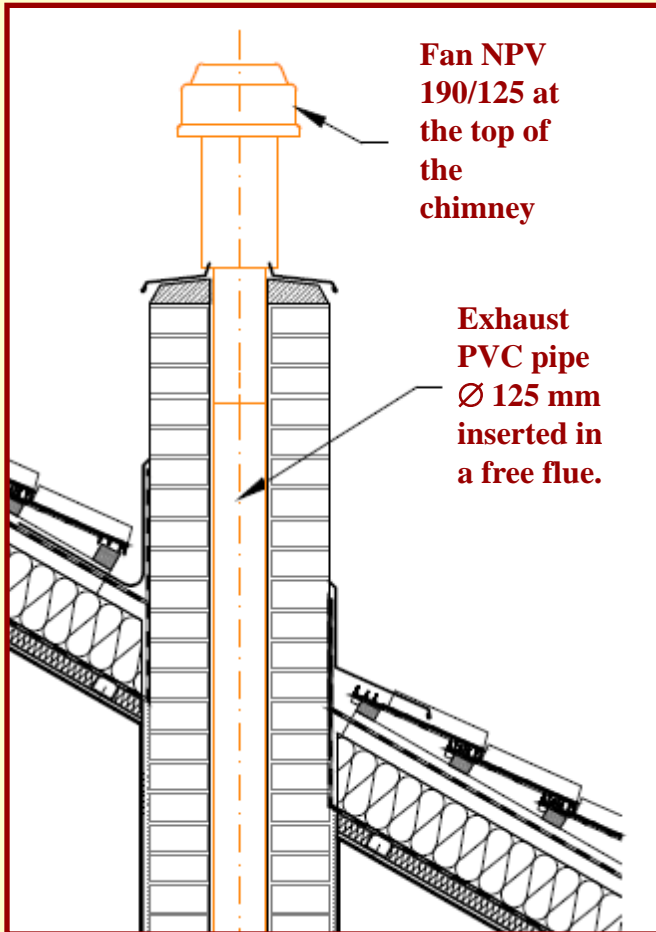
Exhaust PVC pipe Ø 125 mm inserted in a free flue. Fan installed above the roof.



Details of remedial measures

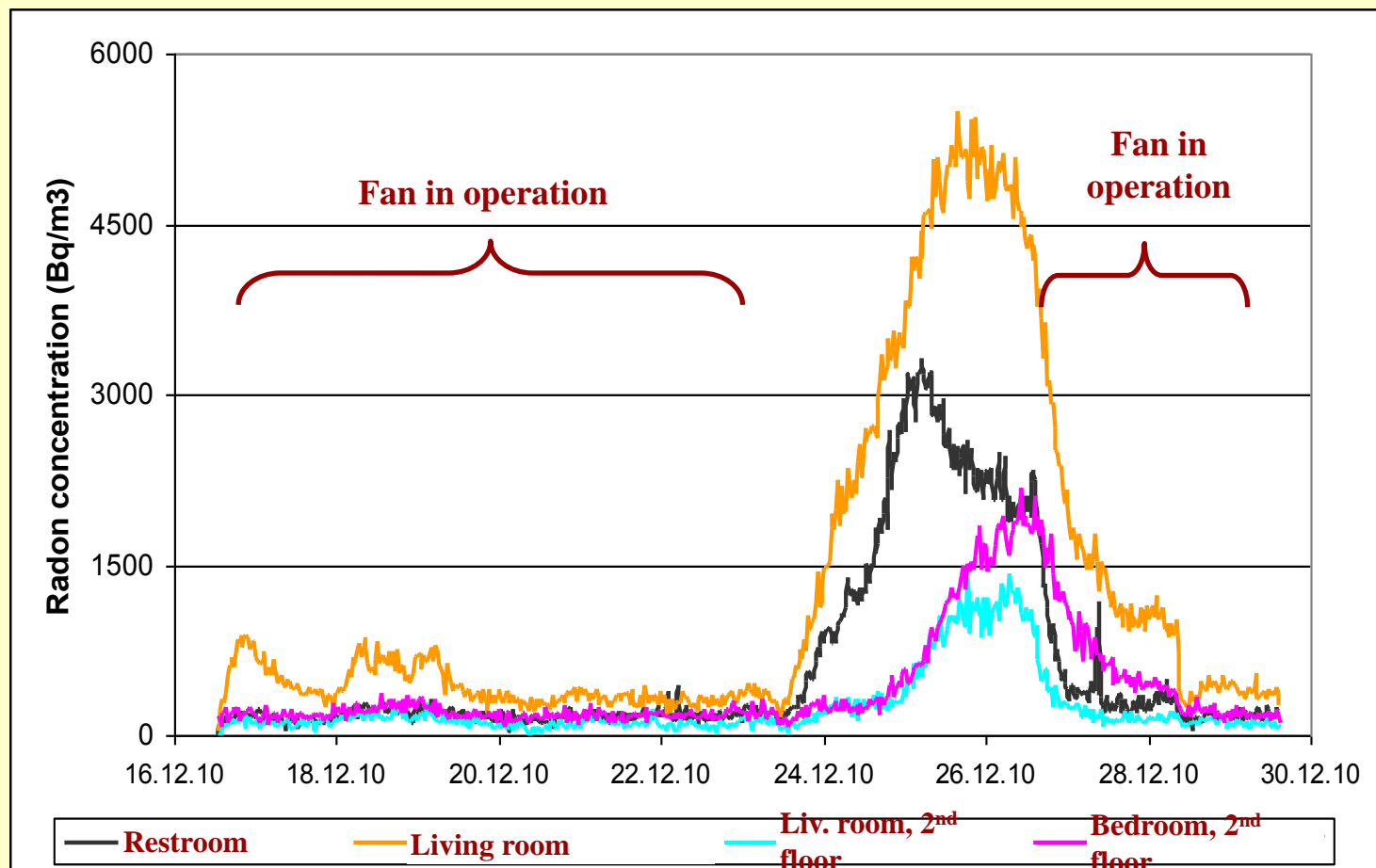


Details of remedial measures

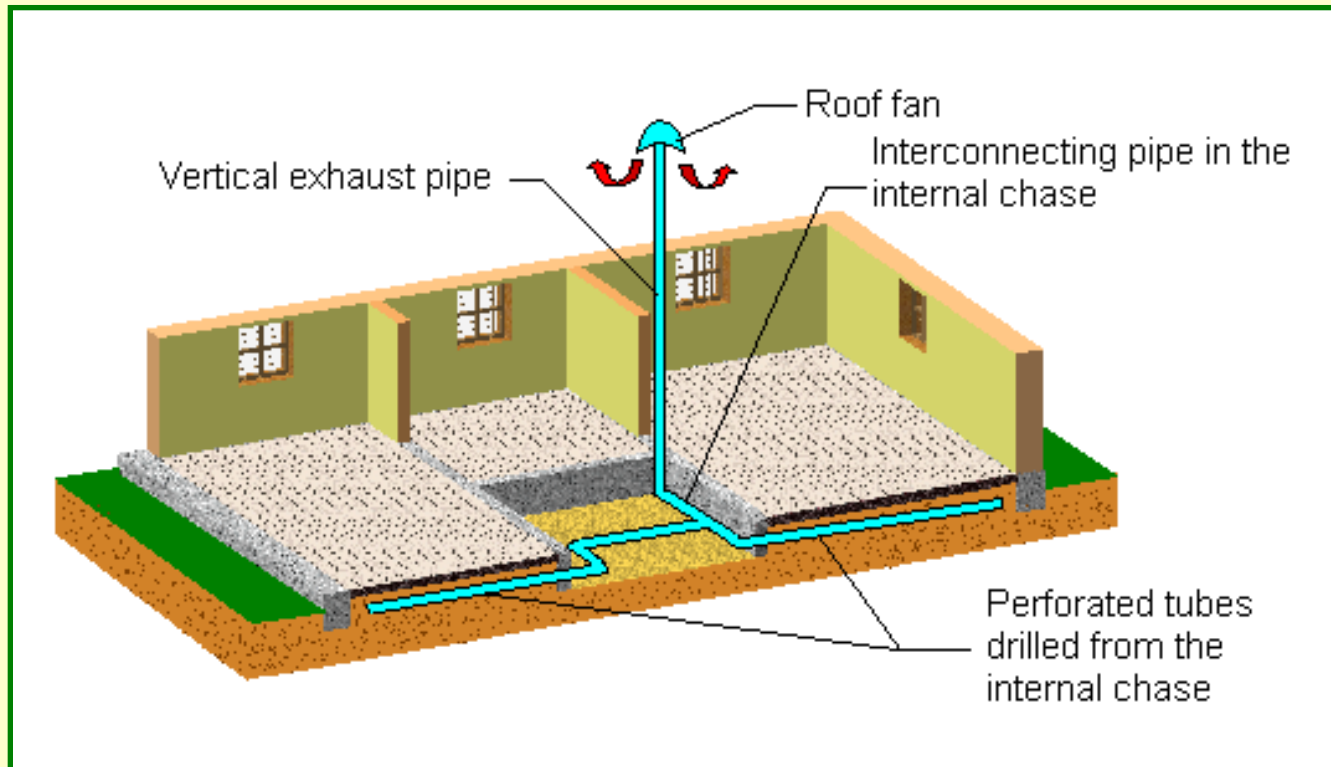


Indoor radon concentration after remediation

During active ventilation indoor radon concentration decreased to the mean value 223 Bq/m³.



Perforated tubes drilled from the internal pit



THANK YOU FOR YOUR ATTENTION