



# Mitigation of radon in buildings and workplaces

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# Content

- Radon sources and entry routes into indoor air
- Radon mitigation methods:
  - Sub-slab depressurization
  - Improving ventilation
  - Sealing entry routes
- Effectiveness of radon mitigation methods

# Sources of indoor radon

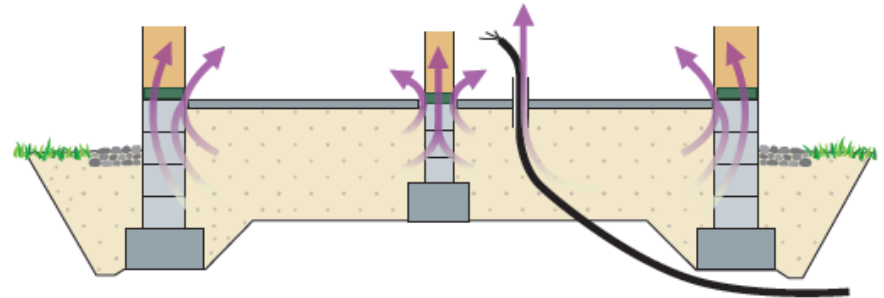
- **Soil under the building**
  - Most important
- Filling materials in the foundation and base floor
- Construction materials
  - Addition of 40 Bq/m<sup>3</sup> on average
- Water from drilled well
  - 1000 Bq/l => 40 Bq/m<sup>3</sup>
  - Average 460 Bq/l



# Entry routes in dwellings

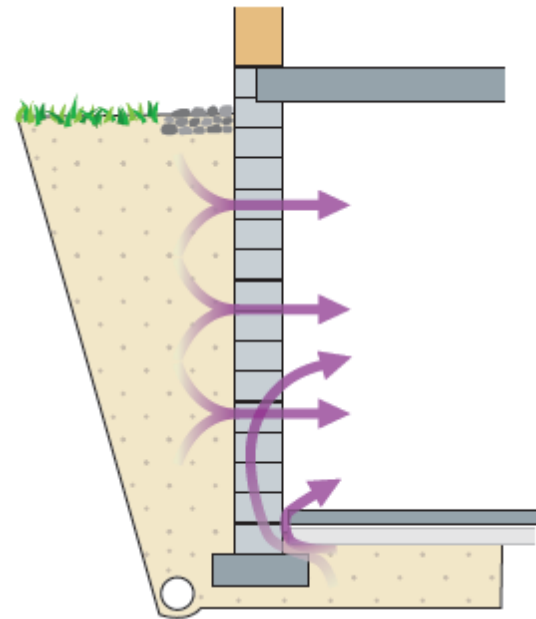
## Slab on ground

- Gap between foundation wall and floor slab
- Permeable lightweight aggregate concrete blocks
- Non-sealed pipe penetrations



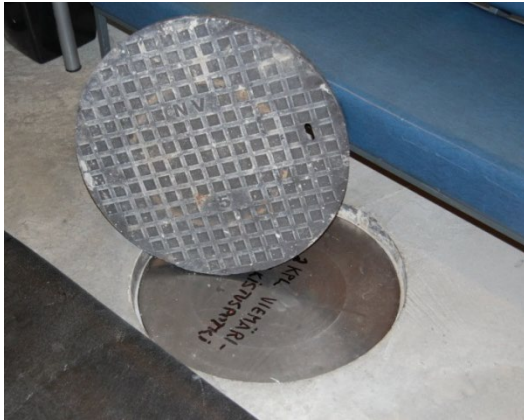
## Basement or semi-basement

- Light-weight concrete blocks and hollow-block walls in contact with soil



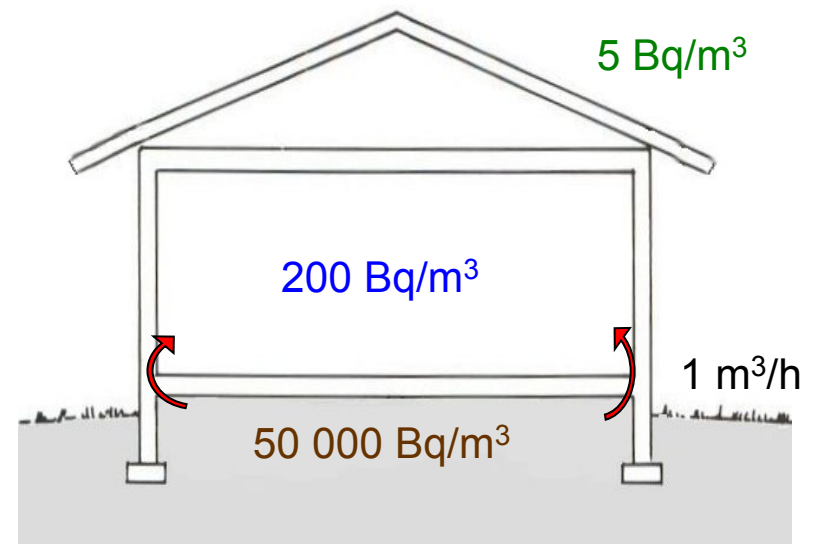
# Entry routes in big buildings

- Joints of the base floor and walls, including columns
- Movement joints
- Pipe and cable penetrations
- Inspection hatch of subsoil drains



# Leakage air flows from the soil

- Leakage air flows are caused by a negative pressure in the building
  - Temperature difference between indoors and outdoors
  - Mechanical ventilation (supply and exhaust 2–5 Pa, exhaust 5–10 Pa)
  - Wind
- Even a small air flow can increase the radon concentration above the reference level
- Even a small gap enables leakages
- Leakage air flows are dominated by the air permeability of the soil
  - Largest radon concentrations have been found in houses build on gravel, e.g. on eskers



# Radon mitigation methods

In buildings

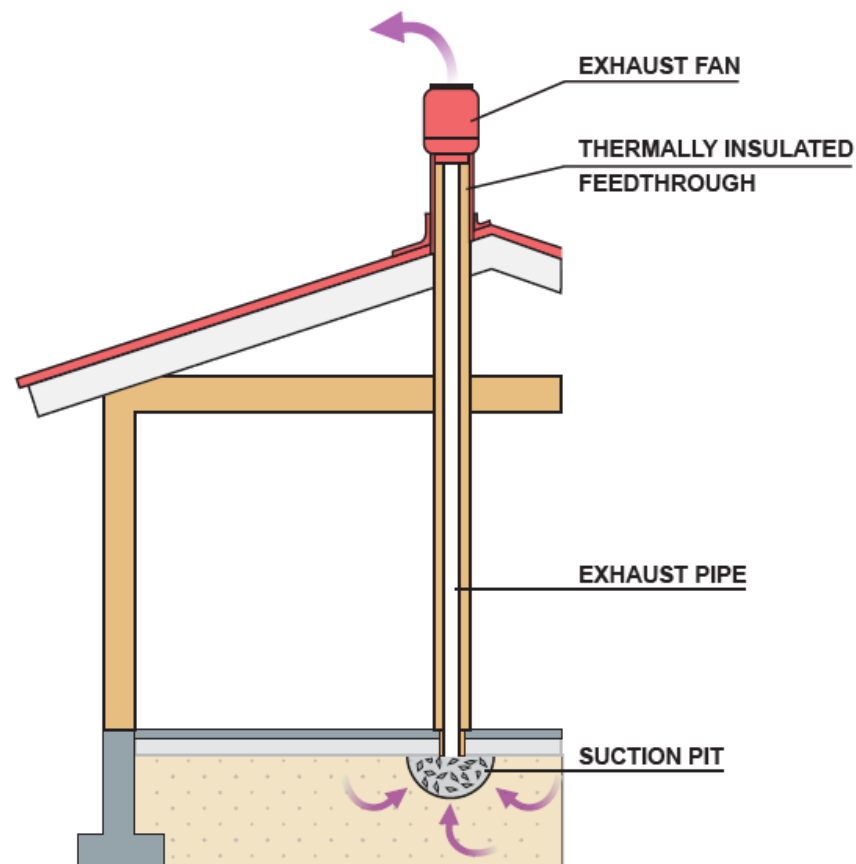
- Sub-slab depressurization
- Radon well
- Improving ventilation
- Sealing entry routes

In mines and underground excavation works

- Improving ventilation
- Control of ground water (pumping stations)
- (Limiting working time)

# Sub-slab depressurization (SSD)

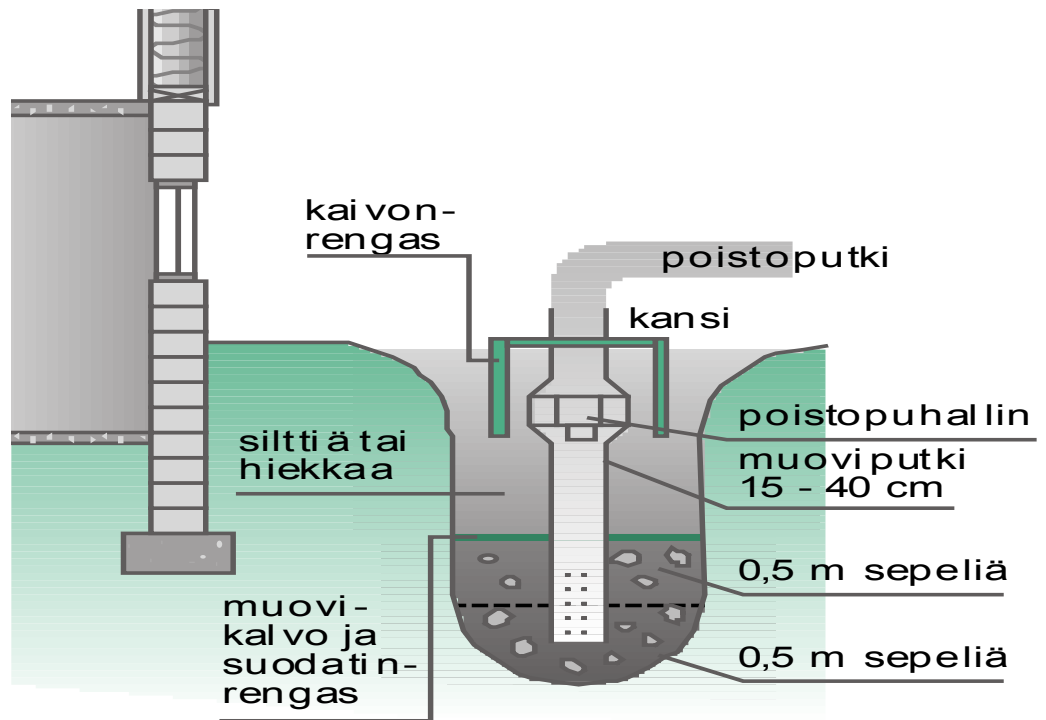
- Common radon mitigation method
  - Forced ventilation of the suction pit using an exhaust fan
- SSD creates negative pressure under the floor slab and also reduces the soil air radon concentration





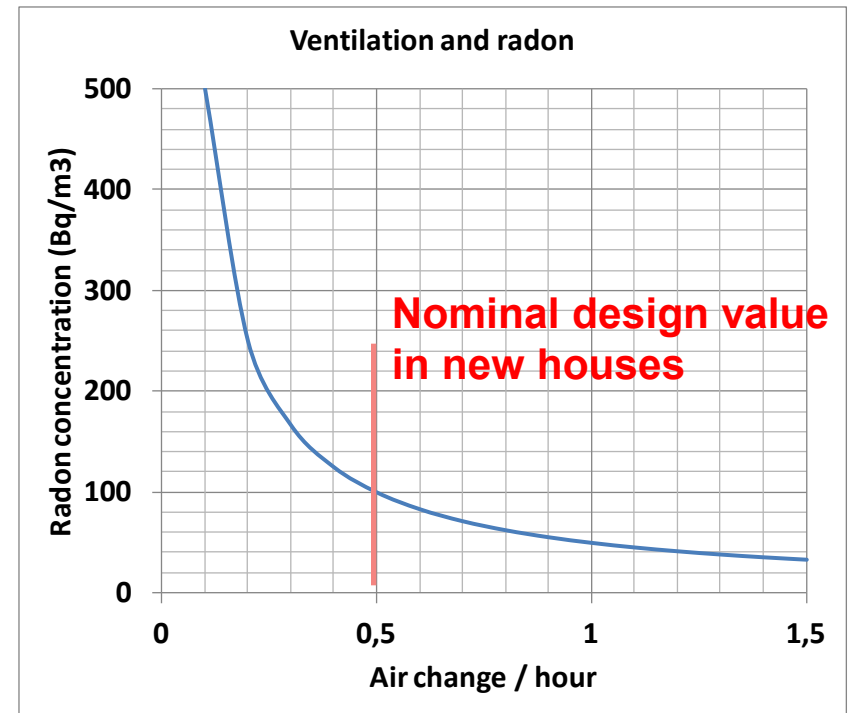
# Radon well

- Can be used only in rough soils, such as sand and gravel
- Suitable for row houses and big buildings as well as detached and semi-detached houses
- Depth 4–5 meters



# Improving ventilation

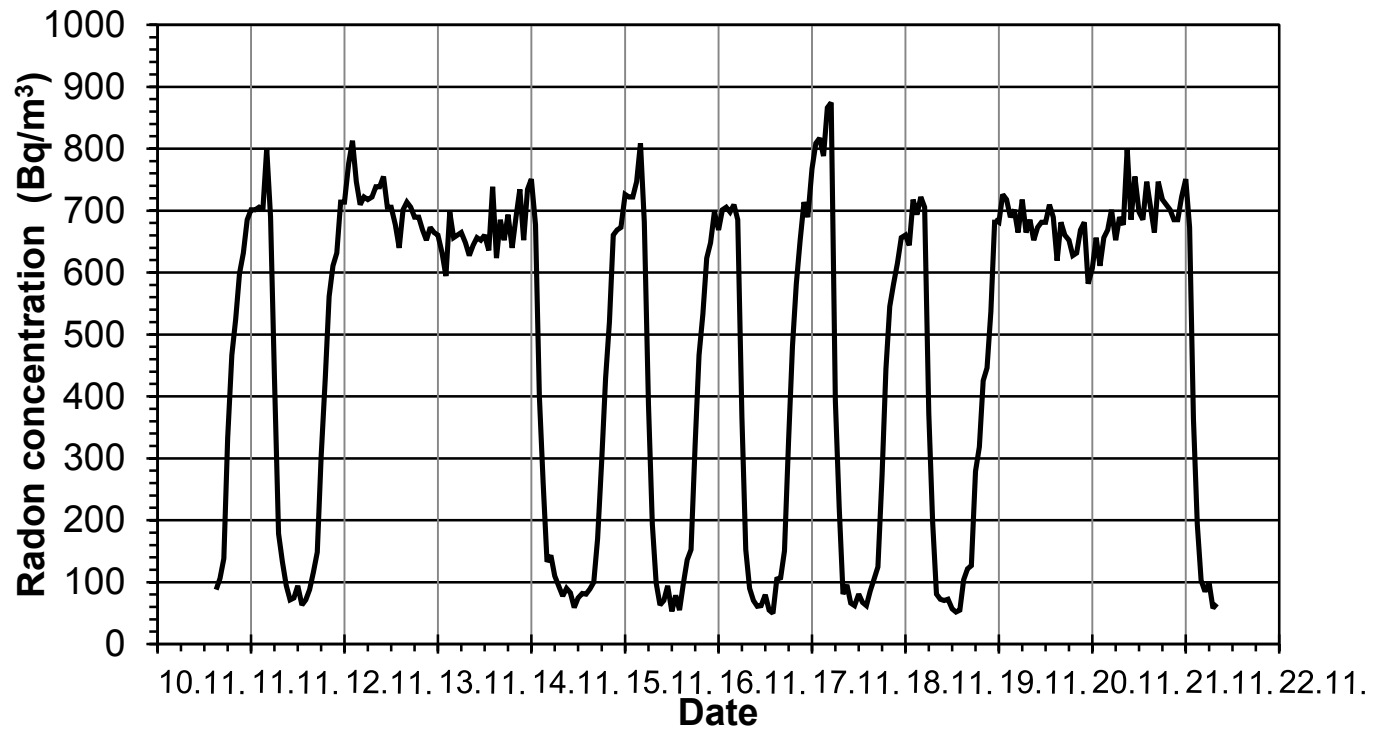
- Can be effective if the initial state of the house ventilation is poor or if the negative pressure is high
- Possible actions in living spaces
  - Opening or adding supply air vents
  - Increasing air exchange of the mechanical ventilation system, but it is important not to increase negative pressure
- Improving ventilation in cellar or in crawl space can also be used



# Characteristics of ventilation at workplaces

- Mechanical ventilation is operated at higher level during working hours than at other times
  - Supply and exhaust ventilation or exhaust ventilation only
  - Ventilation is shut down for nights and weekends to save energy (power consumption of fans and heating of the building)
- Separate exhaust ventilation in toilets and staircases are usually operated continuously
  - Higher negative pressure during nights and weekends

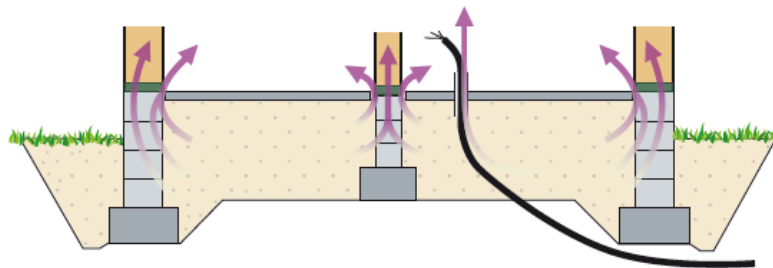
# High variation of radon concentration at a workplace



- Average during working hours 80 Bq/m<sup>3</sup>
- Average of the whole measurement time (11 days): 480 Bq/m<sup>3</sup>
- Long term (> 2 months) average radon concentration: 500 Bq/m<sup>3</sup>

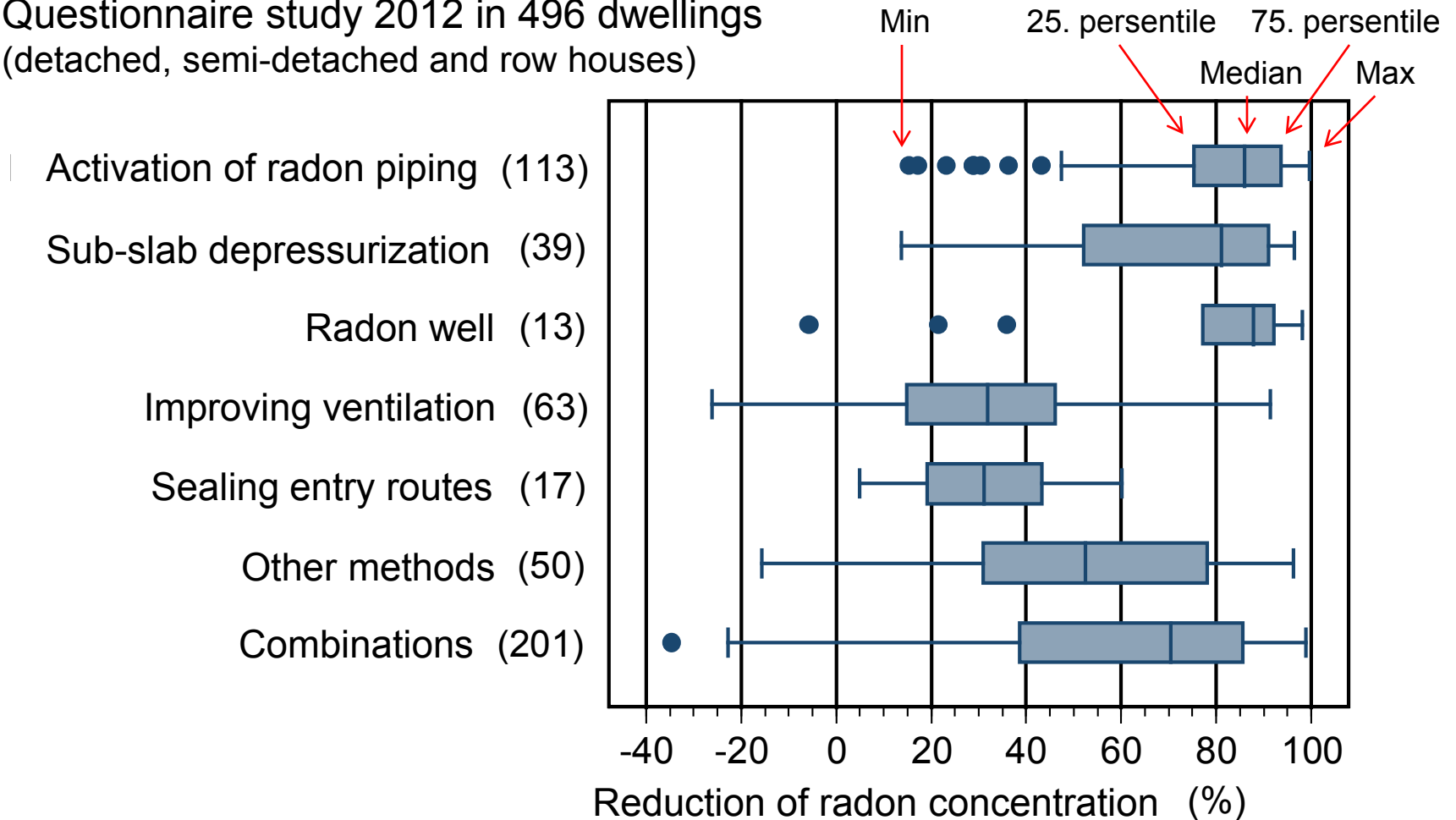
# Sealing entry routes

- Typical entry routes from the ground
  - cracks, gaps, holes and pipe penetrations in the floor slab and walls in contact with soil
- Complete sealing often very demanding depending on the structures of the building
  - Easier with concrete walls



# Effectiveness of radon mitigation methods

- Questionnaire study 2012 in 496 dwellings (detached, semi-detached and row houses)



# Summary

- Factors increasing indoor radon concentrations
  - Cold climate and airtight houses resulting higher negative pressure levels
  - Way of construction of the base floor and foundation (ground supported floor slab) and adjustment of mechanical ventilation
  - Permeable soil types (eskers)
- Most efficient radon mitigation methods are sub-slab depressurization and radon well
  - Typical reduction of radon concentrations 70–90 %
- Future work
  - Sustainability of radon mitigation methods
  - Effectiveness of sealing entry routes at workplaces and other buildings made of concrete elements?



**Thank you for your attention!**