ZAG

ZAVOD ZA GRADBENIŠTVO SLOVENIJE

SLOVENIAN NATIONAL BUILDING AND CIVIL ENGINEERING INSTITUTE

Radon mitigation in Slovenia

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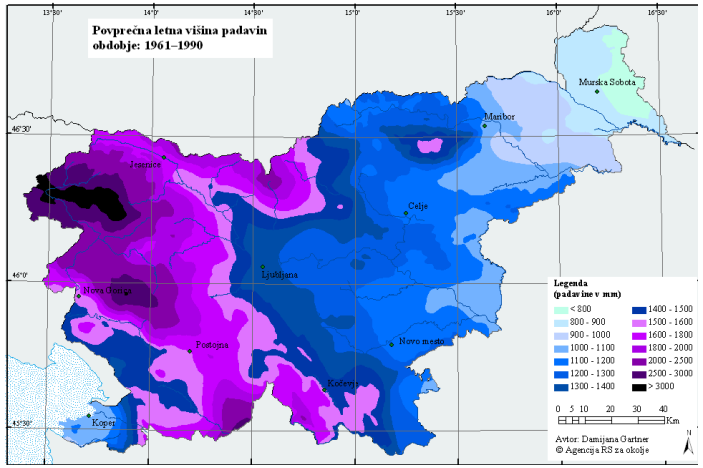
Radon protection conference

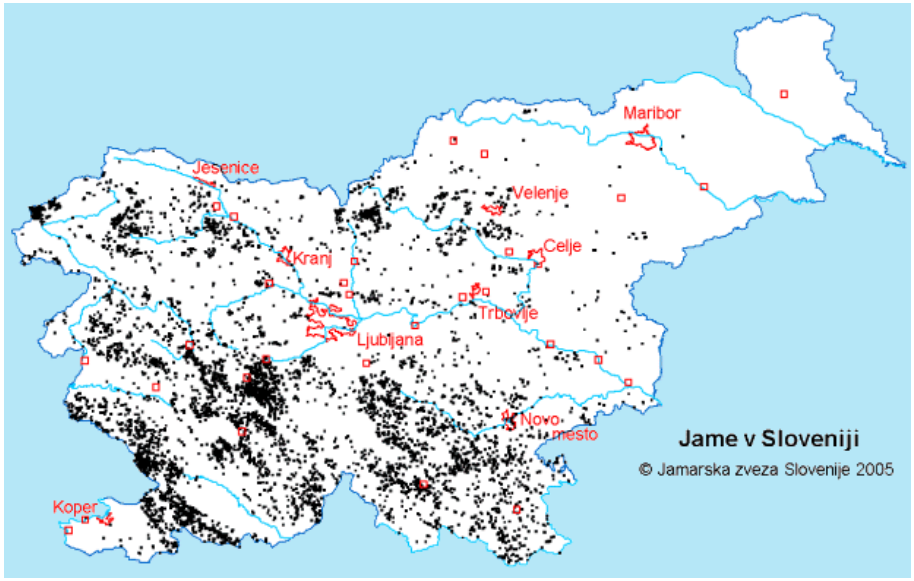
Slovenia – General data

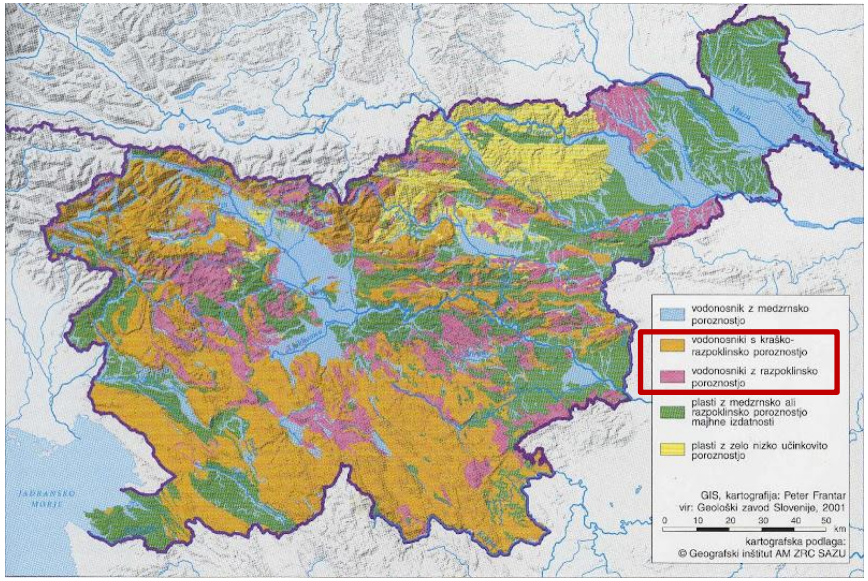
- Central European country
- 2 million inhabitants
- 3 climatic regions
  - Snow in winter
  - Medium rain
- Neighbouring
  - Croatia
  - Italy
  - Austria
  - Hungary



Slovenia and karst terrain

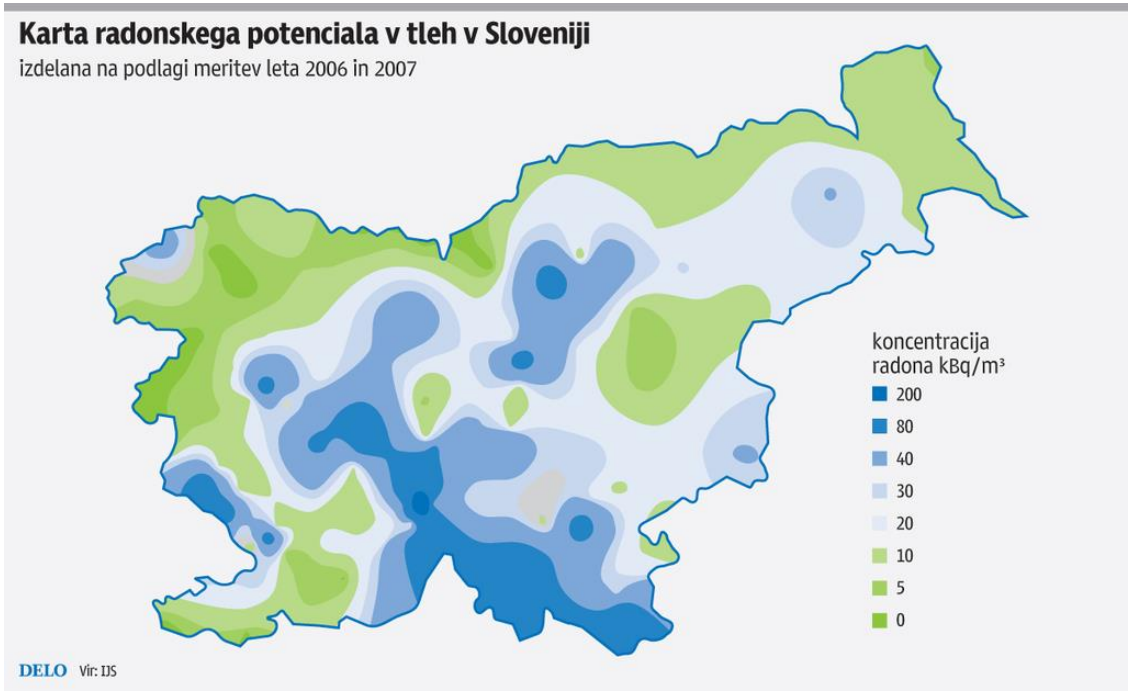
- Left: known caves
- Right: terrain type, regarding permeability





Meaurements of radon in Slovenia

- Systematic research for some 20 years
- Shown: ground radon potential
- Detailed surveys of indoor radon in schools and kindergartens



Buildings

- Building stock
  - Approx. 600.000 buildings, 500.000 single houses
  - Age varies
  - Building type – typical for Central Europe
- Influencing building parameters:
  - increase of tightness,
  - increase of indoor temperature

Typical building stock

- Before 1945 – CE
- 1945-1970 – brick, poor practice
- 1970-1980 gradual improvement

- Rdon risk is found particularly in class 1 and 2 SHF

Contruction Year Class	Additional Classification	SFH Single Family House	TH Terraced House	MFH Multi Family House	AB Apartment Block
... 1945	generic (Tipična)	 SI.N.SFH.01.Gen	 SI.N.TH.01.Gen	 SI.N.MFH.01.Gen	 SI.N.AB.01.Gen
1946 ... 1970	generic (Tipična)	 SI.N.SFH.02.Gen	 SI.N.TH.02.Gen	 SI.N.MFH.02.Gen	 SI.N.AB.02.Gen
1971 ... 1980	generic (Tipična)	 SI.N.SFH.03.Gen	 SI.N.TH.03.Gen	 SI.N.MFH.03.Gen	 SI.N.AB.03.Gen
1981 ... 2001	generic (Tipična)	 SI.N.SFH.04.Gen	 SI.N.TH.04.Gen	 SI.N.MFH.04.Gen	 SI.N.AB.04.Gen
2002 ... 2008	generic (Tipična)	 SI.N.SFH.05.Gen	 SI.N.TH.05.Gen	 SI.N.MFH.05.Gen	 SI.N.AB.05.Gen
2009 ...	generic (Tipična)	 SI.N.SFH.06.Gen	 SI.N.TH.06.Gen	 SI.N.MFH.06.Gen	 SI.N.AB.06.Gen

Mitigation

- Serious mitigation for 20 years
- Sources
  - Karst terrain
  - High U content in soil
  - Fly ash
- Based on EPA guidelines
- Readon prevention – new build: (only) 3 cases

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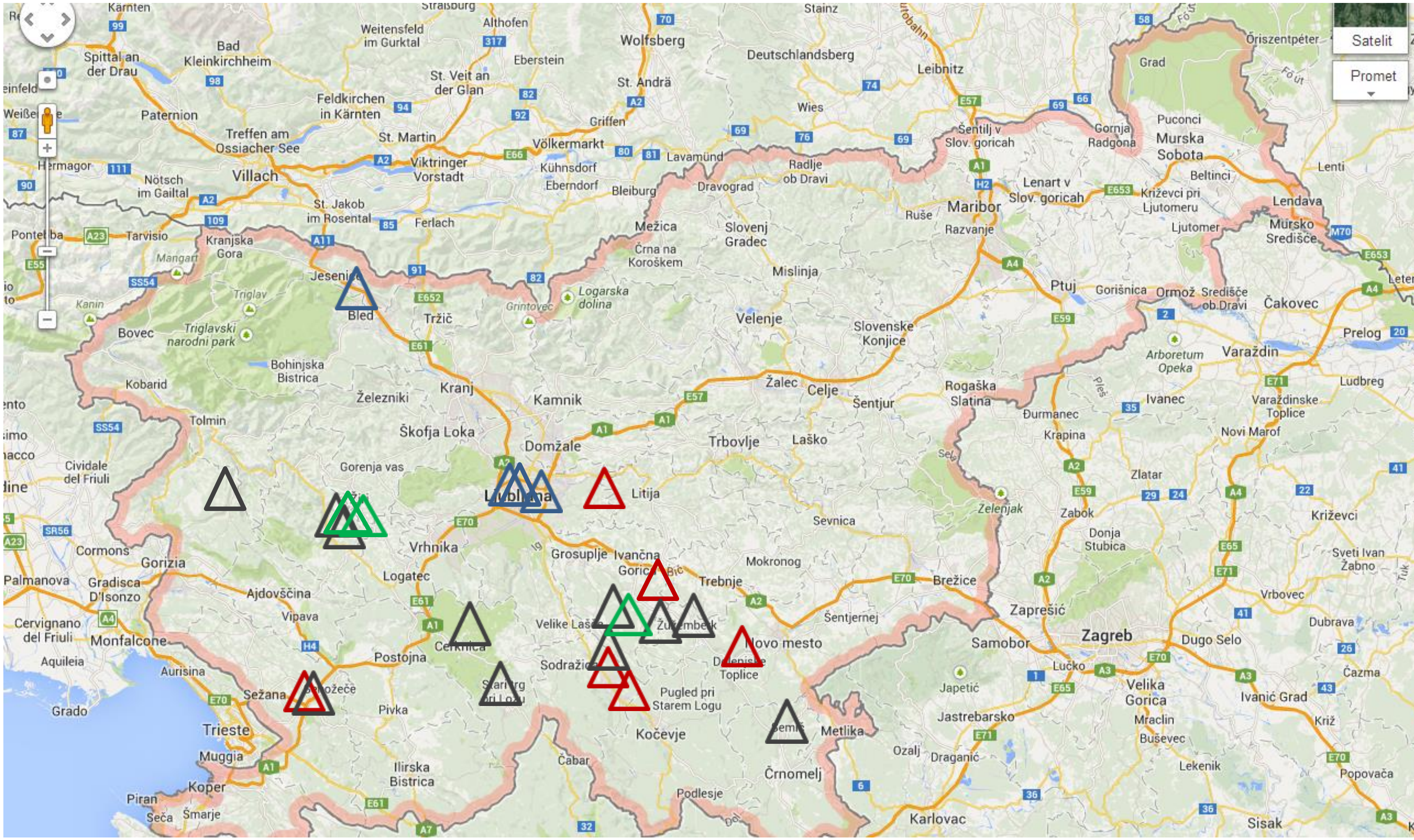
Current changes in buildings

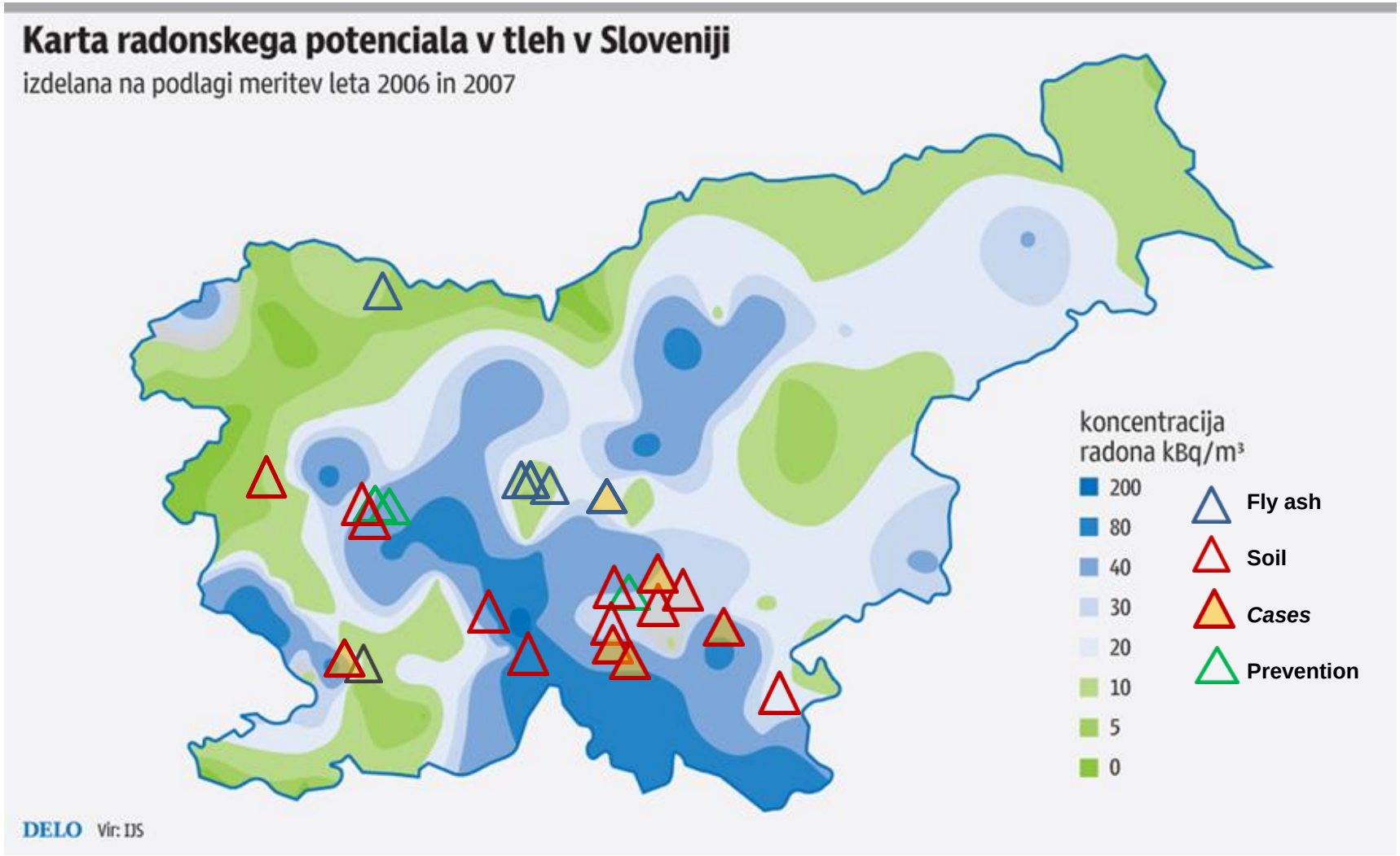
- Energy efficiency measures cause
  - Tighter envelopes
  - Controlled ventilation / over- or underpressure
- Genaral situation
  - Lower awareness of risks generally (radon, earthquake, flood) or
  - Denial of rosk
  - Mobility and real estate prices push buildings on riskier areas (e.g. South of Ljubljana)

Cases



Satelit
Promet
Kärnten
Spittal an der Drau
Bad Kleinkirchheim
Weitensfeld im Gurktal
Althofen
Wolfsberg
Stainz
Deutschlandsberg
Leibnitz
Eberstein
St. Veit an der Glan
St. Andrä
Feldkirchen in Kärnten
Paternion
Treffen am Ossiacher See
St. Martin
Griffen
Völkermarkt
Wies
Šentilj v Slov. goricah
Gornja Radgona
Puconci
Murska Sobota
Grad
Őriszentpéter
Villach
Nötsch im Gailtal
Viktringer Vorstadt
Kühnsdorf
Eberndorf
Lavamünd
Radlje ob Dravi
Dravograd
Bleiburg
Lenart v Slov. goricah
Križevci pri Ljutomeru
Beltinci
Lendava
Maribor
Ruše
Razvanje
Ljutomer
Mursko Središće
St. Jakob im Rosental
Ferlach
Tarvisio
Kranjska Gora
Mežica
Črna na Koroškem
Slovenj Gradec
Mislinja
Jesenice
Bled
Tržič
Logarska dolina
Ptuj
Gorišnica
Ormož
Središče ob Dravi
Čakovec
Prelog
Bovec
Triglav
Triglavski narodni park
Velenje
Slovenske Konjice
Arboretum Opeka
Varaždin
Bohinjska Bistrica
Kobarid
Kranj
Železniki
Kamnik
Žalec
Celje
Šentjur
Rogaška Slatina
Ivanec
Varaždinske Toplice
Ludbreg
Tolmin
Škofja Loka
Domžale
Trbovlje
Laško
Krapina
Novi Marof
Cividale del Friuli
Gorenja vas
Ljubljana
Litija
Zlatar
Sevnica
Zelenjak
Zabok
Donja Stubica
Križevci
Cormons
Gorizia
Vrhnika
Grosuplje
Ivančna Gorica
Mokronog
Trebnje
Brežice
Sveti Ivan Žabno
Palmanova
Gradisca D'Isonzo
Ajdovščina
Logatec
Vrbovec
Vipava
Velike Lašče
Žužemberk
Šentjernej
Zaprešić
Cervignano del Friuli
Monfalcone
Cerknica
Novo mesto
Samobor
Zagreb
Dugo Selo
Dubrava
Aquileia
Aurisina
Postojna
Sodražica
Dolenjske Toplice
Lučko
Čazma
Sežana
Stari trg pri Ložu
Pugled pri Starem Logu
Japetić
Velika Gorica
Ivanić Grad
Grado
Pivka
Jastrebarsko
Mraclin
Križ
Trieste
Kočevje
Metlika
Ozalj
Draganić
Buševec
Muggia
Čabar
Ilirska Bistrica
Črnomelj
Lekenik
Popovača
Koper
Podlesje
Piran
Sečovlje
Šmarje
Karlovac
Sisak

Radon source per case



Cases – general workflow applied

- Blueprints analyses
- Studying *Rn* measurements
- Interview employees and locals
- Measurements and assessment
- Design a strategy
- Apply a pilot system
- Evaluate effect
- Correct if neccesary
- Finalize the system

Listening to the employees

- Different sources (older users, maintenance personell, historic sources)
  - Ussually more reliable than old blueprints!
- Local information
  - Materials
  - Debree use
  - Geological data

Knowing what you are dealing with

- Ussually needed intervention
  - Opening the structure
  - Water barrier?
- Often found critical: knowledge – details on shafts
  - Unexpected difficulties (e.g. Sealed access)
- Important: detailed inspection to minimize intrusion

Details

Evaluating planned strategy

- Permeability measurements



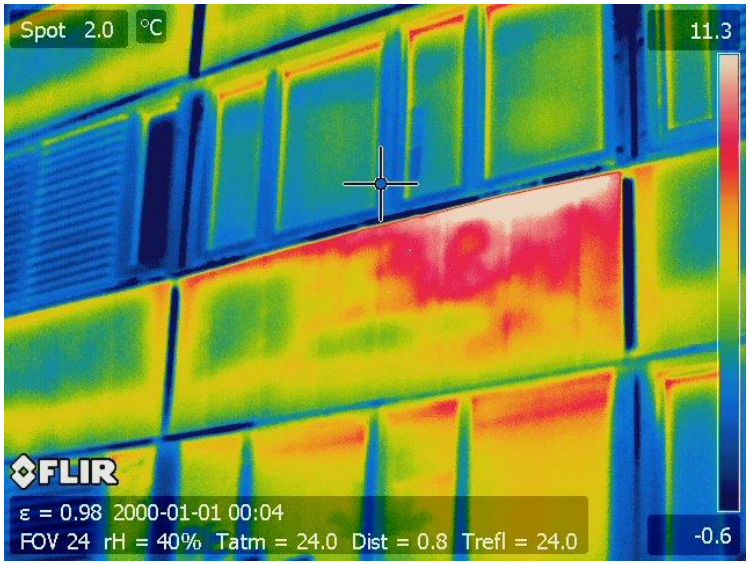


Difficulties

- Sometimes no pressure communication is found
  - Very tight or very loose structure

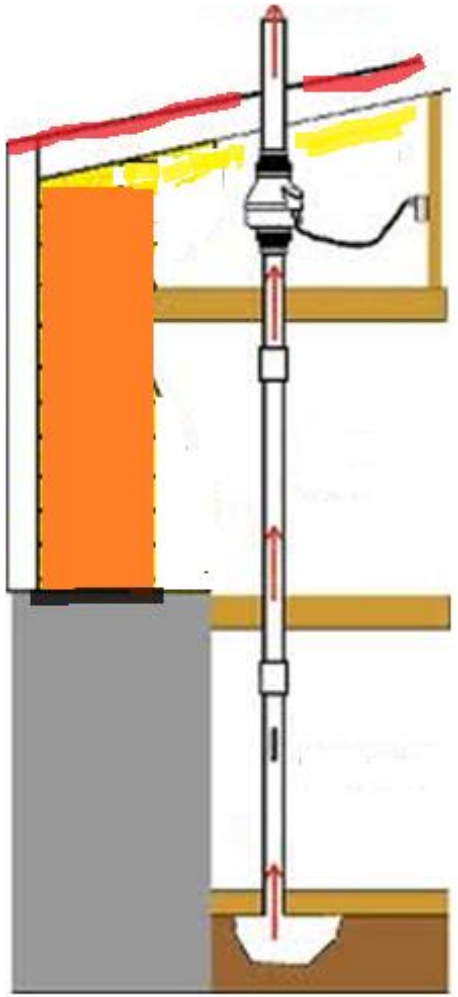
Evaluation of building tightness

- Crucial in air pressurization systems
- May predict effects of energy refurbishment



Different strategies considered

- Local underpressure
  - SSD (“sub-slab depresurisation”) – often used in Slovenia
  - SMD (“sub-membrane depresurisation”) – very seldom used in Slovenia, results not so good
  - DTD (“drain – tile” depressurisation) – never used in Slovenia as is originally designed
  - Drain / shaft system – used if posible, results are good
- Overpressurization
  - Considered in latest case (not presented)

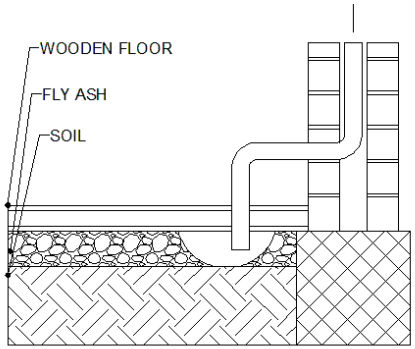


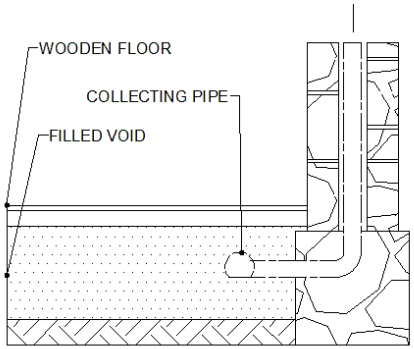
Systems execution – different variations

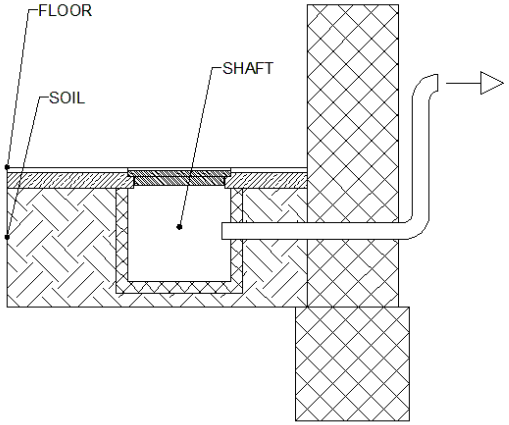
Critical in execution (found)

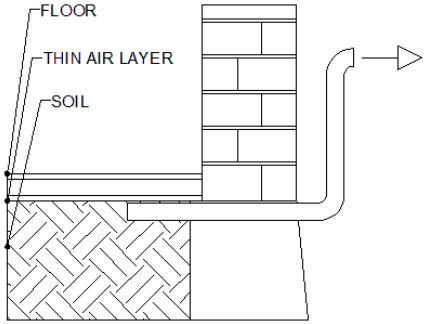
- Fan selection
- Controll absence
- Change of piping material
- Caulking material

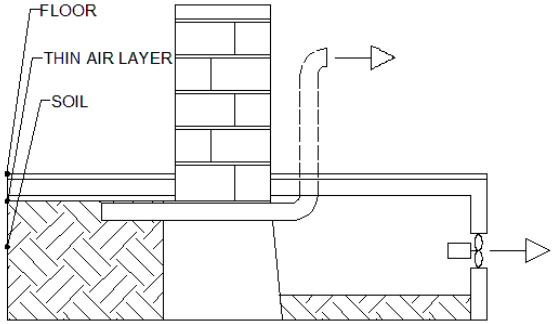
Mitigation principle used in selected cases

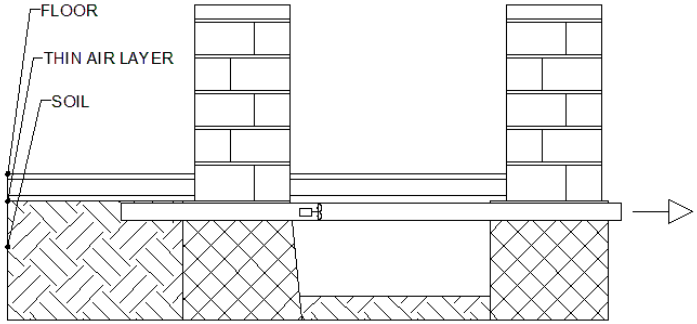










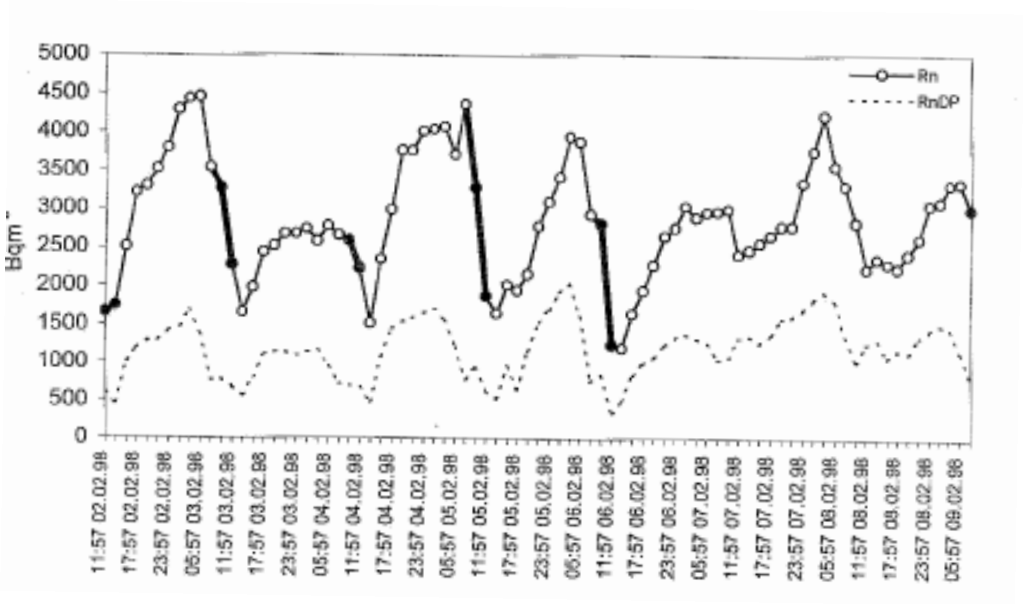


Results of mitigation

#	Building	Basic building description	Radon source	$C_{Rn,initial}$ [Bq/m^3]	$C_{Rn,inter}$ [Bq/m^3]	$C_{Rn,mit}$ [Bq/m^3]	Mitig. [year]	Mitig. principle
1	Janče	Wooden floor, fly-ash in the structure.	Fly ash in the floor structure	Over 1.000	less than 400	-	1997	SSD
2	Lokev pri Sežani	Wooden floor, beneath large void (estimated 1,5 m^3/m^2 floor)	Soil	> 1.000	200-850	-	1997	New floor, SSD
3	Dolenja vas	Concrete floor, long shaft network (piping, sewage)	Soil, radon distributed by shafts	600-4.150	100-3.165	< 100 - 500	1997	Ventilation of shafts + SSD (part)
4	Prevole	Concrete, inaccessible walls	Soil	3.200	Not yet avail.	-	2012	SSD
5	Muljava	Concrete floor on ground, under floor suspected mixed debris	Soil	4.000	380	-	2011	SSD
6	Vavta vas	Concrete (?), stone walls, under floor suspected debris	soil	1.750	340	169	2013	SSD, sealing

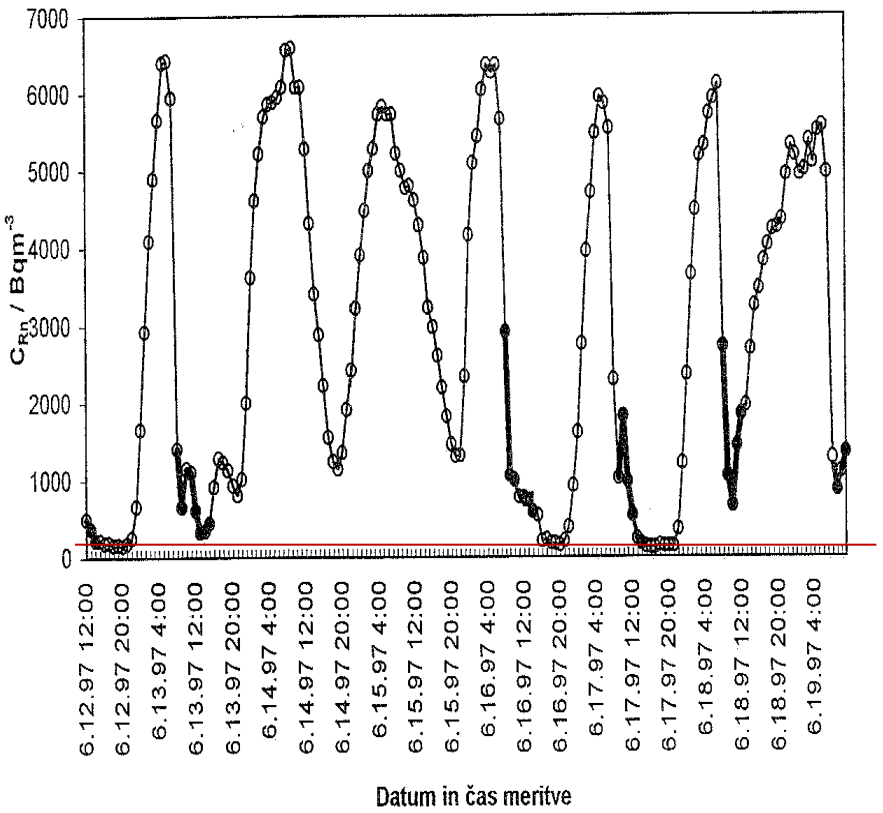
Janče

- Radon source is fly ash in void
- Minigation: removal of fly-ash and ventilation
- Concentration reduction
  - Before:1020 Bq/m^3
  - After: < 400 Bq/m^3



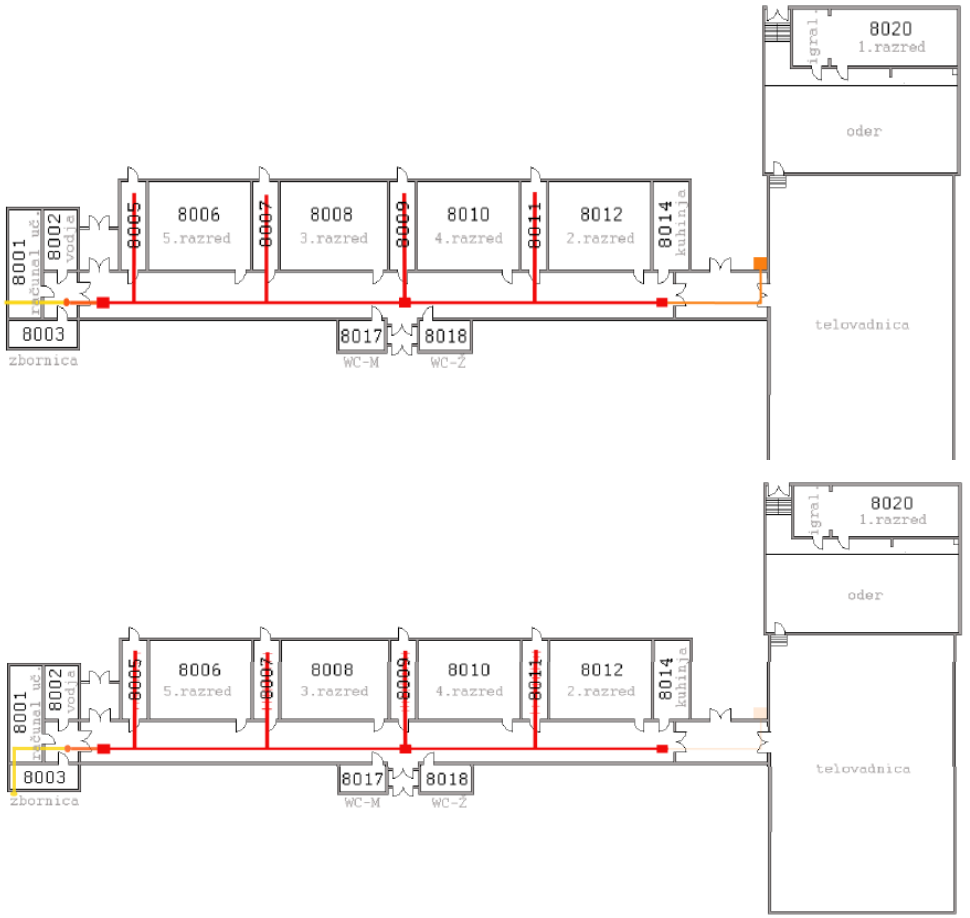
Lokev pri Sežani

- Large void in structure
- Floor reconstructed
  - Drainage system introduced
- Ventilation in chimney
- First operation successful, but fan failure due to poor fan selection
- Secon operation very successful (C_{Rn} < 200 Bq/m^3)



Case Dolenja Vas (1997)

- Initial: 600 - 4000 Bqm^{-3}
- Final: 100 – 500 Bqm^{-3}
- First mitigation: shaft ventilation
- Second mitigation: extension
- Third mitigation:new exhaust



Dolenja vas

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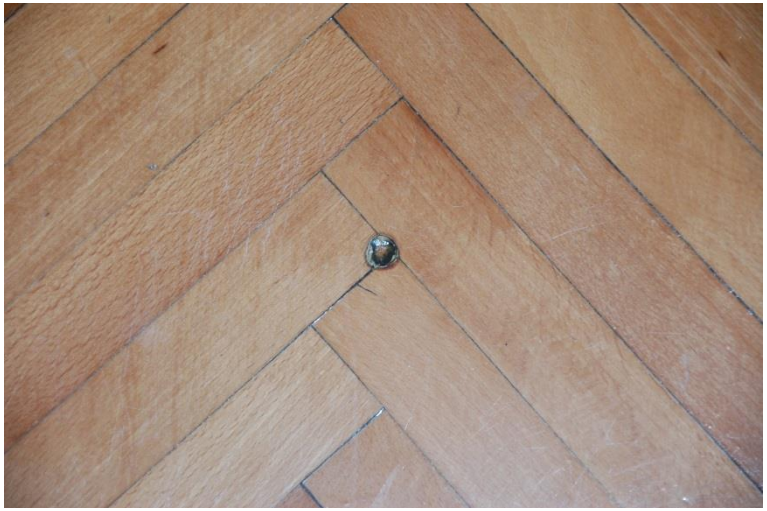
Case Dolenja vas (revisited)



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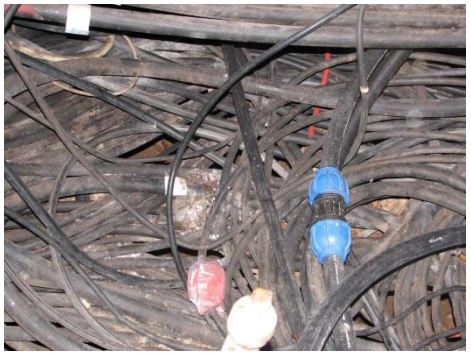
Dolenja vas - revisited

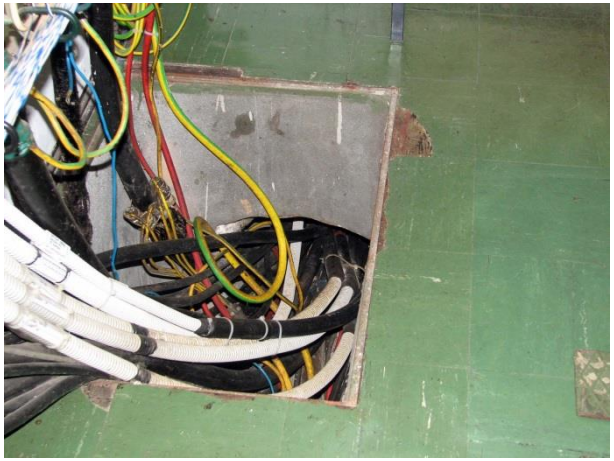
- Mitigation successful when commissioned
- Some modifications done afterwards (facade – air feed-in due to lack of understanding)
- New floor in library
  - Problems with sealed floor (seen very soon)
- Effect of modifications on mitigation system not known
- Change of personell dilutes instructions passed at set-up

Divača („impossible case“)

- Railway controll room
- Radon entering via large floor opening
- Opening connected to underground signalization system
  - No modification allowed due to safety reasons
  - Underground „collector“ about 5 km long – no ventilation or overpressure is possible
- Solution:
  - Instant: increased natural ventilation
  - Discussed (but not realized): mechanical ventilation with overpressure scheme

Divača

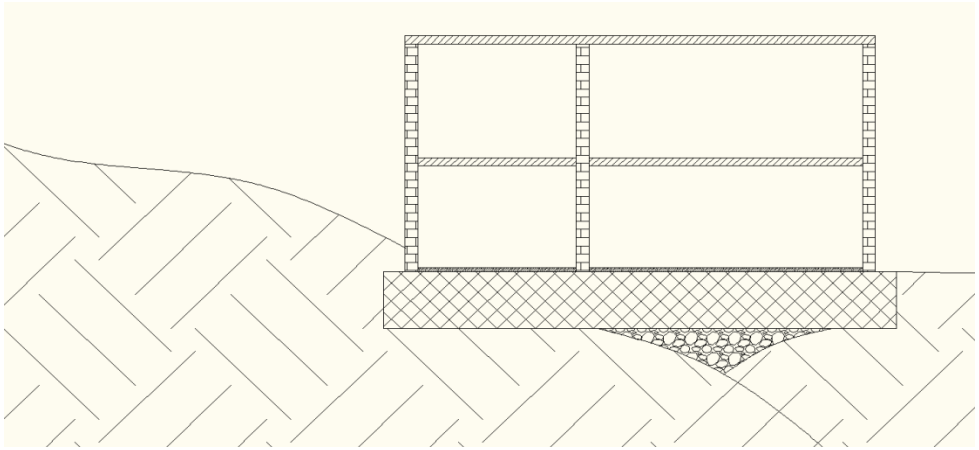




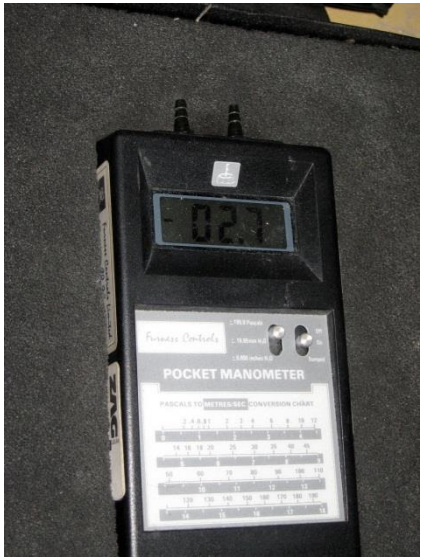
Ribnica („impossible case 2“)

- School exhibits high concentrations
- Analyzing blueprints following is found
  - The building lies on 140 cm thick concrete
  - Reason: pit beneath, leading into minor karst cave
- Exploring the possibilities it becomes clear:
  - No SSD possible due to very high volume to be vetilated
  - No overpressure possible due to central position of rooms in question
  - Sealing virtually impossible in technical rooms due to installations
- Solution:
  - Limited access and use of rooms
  - Exploring possibilities for ventilation via shafts

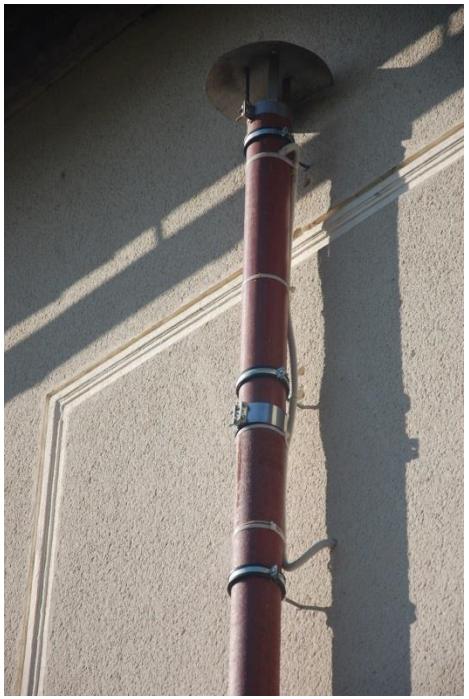
Ribnica



Case Muljava (2010-2011)



Case Muljava



Muljava – sum up

- Concentration
  - Before 4000 Bqm^{-3}
  - After 380 Bqm^{-3}
- The system in crucial points as designed
- Alterations in material selection
  - Increased drag
  - Possible issues on durability / condensation
- No monitoring has been installed to monitor pressure
  - Risk of unnoticed failure
- Results of contol measurements OK

Prevole (2011-2012)

Prevole - analyses

Prevole

Prevole – sum up

- Mitigation strategy was prepared
- Due to small space problems with execution were expected
- The owner modifeid mitigation strategy
  - Without notice or consultation
  - Reason claimed: mainly difficul accessibility
- Real problems:
  - Lack of understanding the princliples of thy system
  - Unskilled technical personell in the building
  - Distributed tasks
  - Organization of school system

Prevole - expectations

- Measurements not yet done
- Expected insufficient effect in spite of obvious effect of the ventilator
  - We hava assessed that the vent is simply moving outside air
- Inspectorate is alerted about the intervention

Case Vavta vas (2012-2013)

Case Vavta vas

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Vavta vas – sum up

- Concentration dropped
  - Before: 1750 Bqm^{-3}
  - After: 170 Bqm^{-3}
- Whole solution approach
  - Design
  - Pilot installation
  - Unofficial measurements
  - Recommendations for improvements
- The system exhibited unexpected behaviour at first
- After adjustement good results
- However: due to lack of concern
  - No official measurements ordered so far
  - No proper commissioning done

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Identified risks

- **Risk 1**: **unauthorized interventions:** Common problem with durability of radon mitigation solution is that in most of the cases additional interventions were done.
- **Risk 2: failure to operate system properly**: radon mitigation system properly executed, however instructions for use not respected. The system was not operated continuously.
- **Risk 3: failure to comply fully with instructions for system execution:** In some cases the radon mitigation system was improperly executed due to lack of understanding of the purpose of individual components.
- **Risk 4: users rely on mitigation system without further measures:** user of the building does not feel any need for further considering concentration monitoring.

Essential measures

- Based on experience following is particularly imporatnt:
  - Radon mitigation has to be done by professionals all the way (design to execution)
  - Good commisioning and maintenance is essential
  - Clear guidelines for radon prevention are needed
    - Radon maps
    - Legislation
    - User guides
  - It seem that awareness in general public has to be high or systems will fail

Conclusions

- Radon can be successfully mitigated
- Plenty of mitigation knowledge available
- However there are „impossible“ cases as well
- Successful rate is high, however:
  - Seldom concentration is not elevated at all
  - Difficult to explain problems often occure, e.g.:
    - Rock in soil
    - Cracked and permeable walls
    - Higher concentration at 1st floor in comparison to ground floor
- Identified risks pose big threat to overall success

Thank you for your attention!