Spatial and temporal variability of soil gas radon concentration and permeability: study performed in Eastern part of Macedonia

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Radon risk

- The radon risk is often defined as the probability that indoor radon exceeds a risk;
- Factors influencing indoor radon concentration are living habits building structure, and soil sub-surface geology.
- The geogenic source of the hazard (or potential risk) at a location or over an area is described by its radon potential.
- The RP is independent from the influence of any building related or living habit factors

Radon potential

- Radon potential is defined:
- $\mathrm{RP} = \frac{C_{Rn}}{-log_{10}k-10}$
- where CRn is the soil gas radon activity concentration express in kBq m3 and k is the soil gas permeability (m2).
- Based on many years of extensive research in the Czech Republic, three categories GP were set Neznal et al. (2004) :
- low (GRP < 10),
- medium (10 < GRP < 35) and
- high (35 < GRP)

Neznal, M., Neznal, M., Matolin, M., Barnet, I., Miksova, J., 2004. The New Method for Assessing the Radon Risk of Building Sites. In: Czech Geol. Survey Special in Papers, vol. 16. Czech Geol. Survey, Prague.

Factor affecting radon concentrations variability in soil gas

I. Factor affecting radon generation in solid matrix – concentration of ^{226}Ra;

II. Radon pathway through soil from generation until its exaltation from the surface;

- Radon transport in soils occurs by diffusion and convection
  - Diffusion is dominant for soil with lover permeability whereas convective transport is dominant for higher permeability
  - Radon transport distances for the same period are higher due to convection process than the diffusion;
- There are three classes:

  • Intergranular • Fracture • Mixed (intergranular and fracture)

of the predominant flow mechanism by which gas will migrate through the unsaturated zone of a specific rock unit and lithology.

M A Lewis, C S Cheney and B É Ódochartaigh. Guide to Permeability Indices , Keyworth, Nottingham British Geological Survey 2006

Factor affecting radon concentrations variability in soil gas

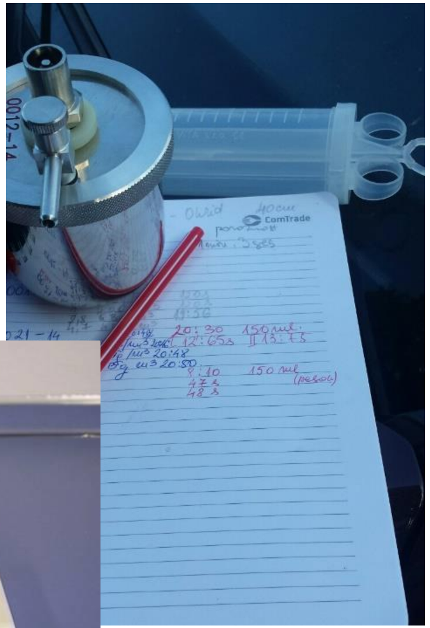
- Soil moisture affecting radon emanation from solid matrix - dominantly as well radon transport
  - Lower soil moisture: higher radon emanation rate and higher transport distance;
- Soils also contain organic material which can affect the overall permeability, which may be very different to that of the underlying rock units.

Objective

- To investigate relationship between geological formations under relatively small area with **soil gas radon concentration and permeability as well as radon potential** spatial and temporal variability;
- To investigate correlations between indoor radon concentrations measurements and radon potentials determined from two period of the year.

Measurements

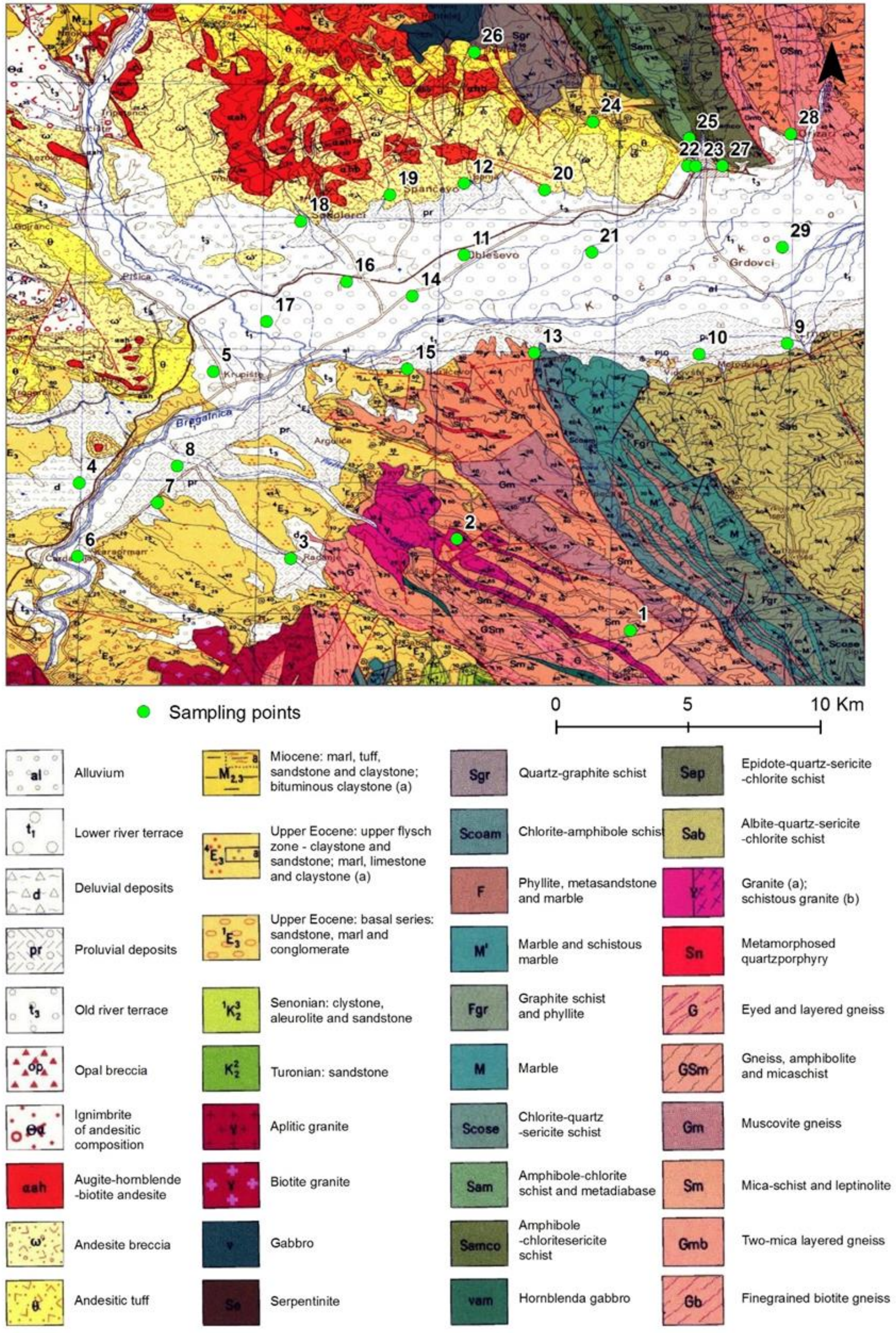
- The measurements carried out in 39 primary school yards in four neighboring municipalities of Eastern Macedonia.
- At each location, the radon was sampled at 80 cm depth and measured by ionization chamber.
- Using the RADON-JOK equipment the measurement of permeability was performed in the same point.
- The infield campaigns were conducted in January and June 2016.
- The indoor radon concentrations were measured in the same schools with nuclear track detectors, exposed: from January to



Area geological characterization

- In geotectonic terms the investigated area belongs to the edge portion of the Vardar Zone and the Serbian-Macedonian mass.
- In geological structure of the region dominate the Serbian-Macedonian mass metamorphic rocks from the upper and lower metamorphic complex represented by granites and schists with different mineral composition and varying metamorphism.
- In the segment that belongs to the Vardar zone represented magmatic rocks (granites), volcanic rocks of Tertiary age (Latina andesite's and Quartz latite) and sedimentary rocks and flysch characters along the river Bregalnica alluvial sediments)

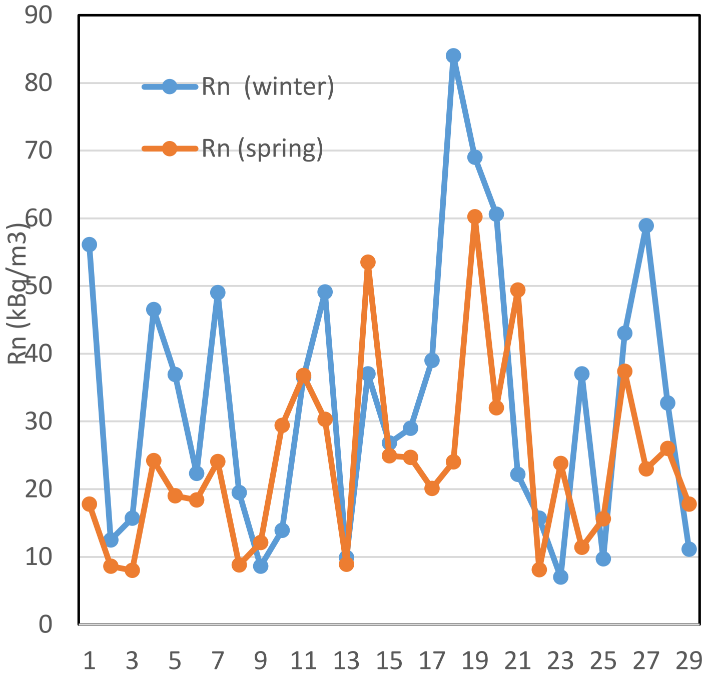
Geological map of the investigated area. Indoor radon concentrations measured in different lithostratigrafic units.



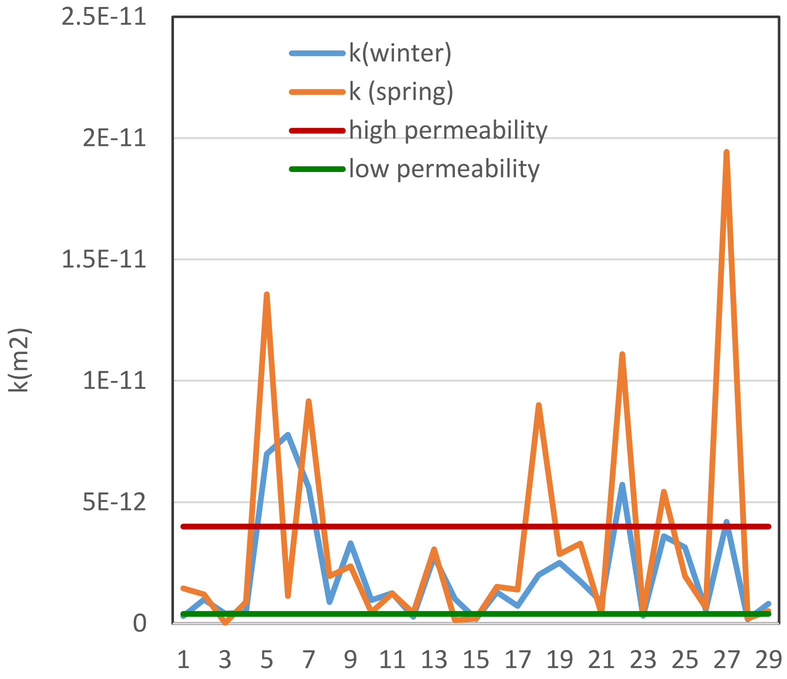
Results of measurements

Statistical analysis have been shown:

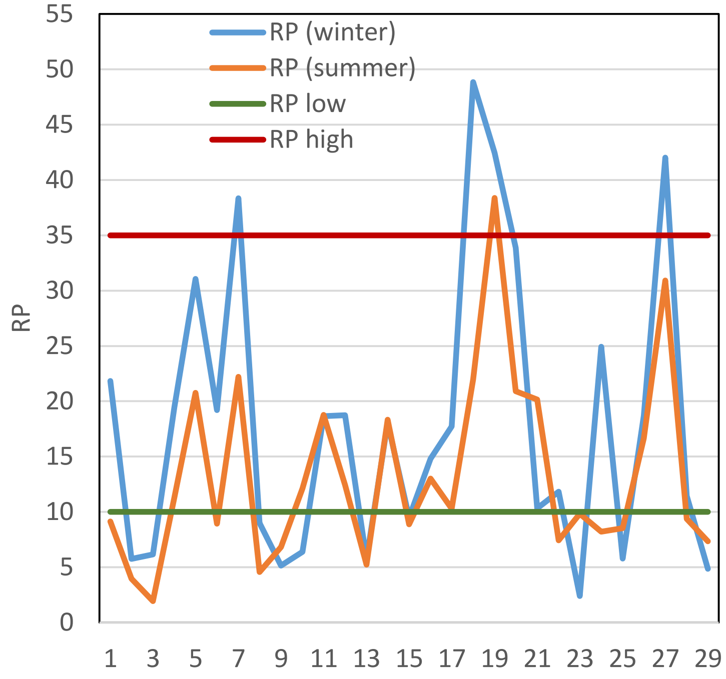
The temporal variation was significant for Rn but not for permeability and RP



Radon concentration measurements in both periods



Soil permeability measured in both periods

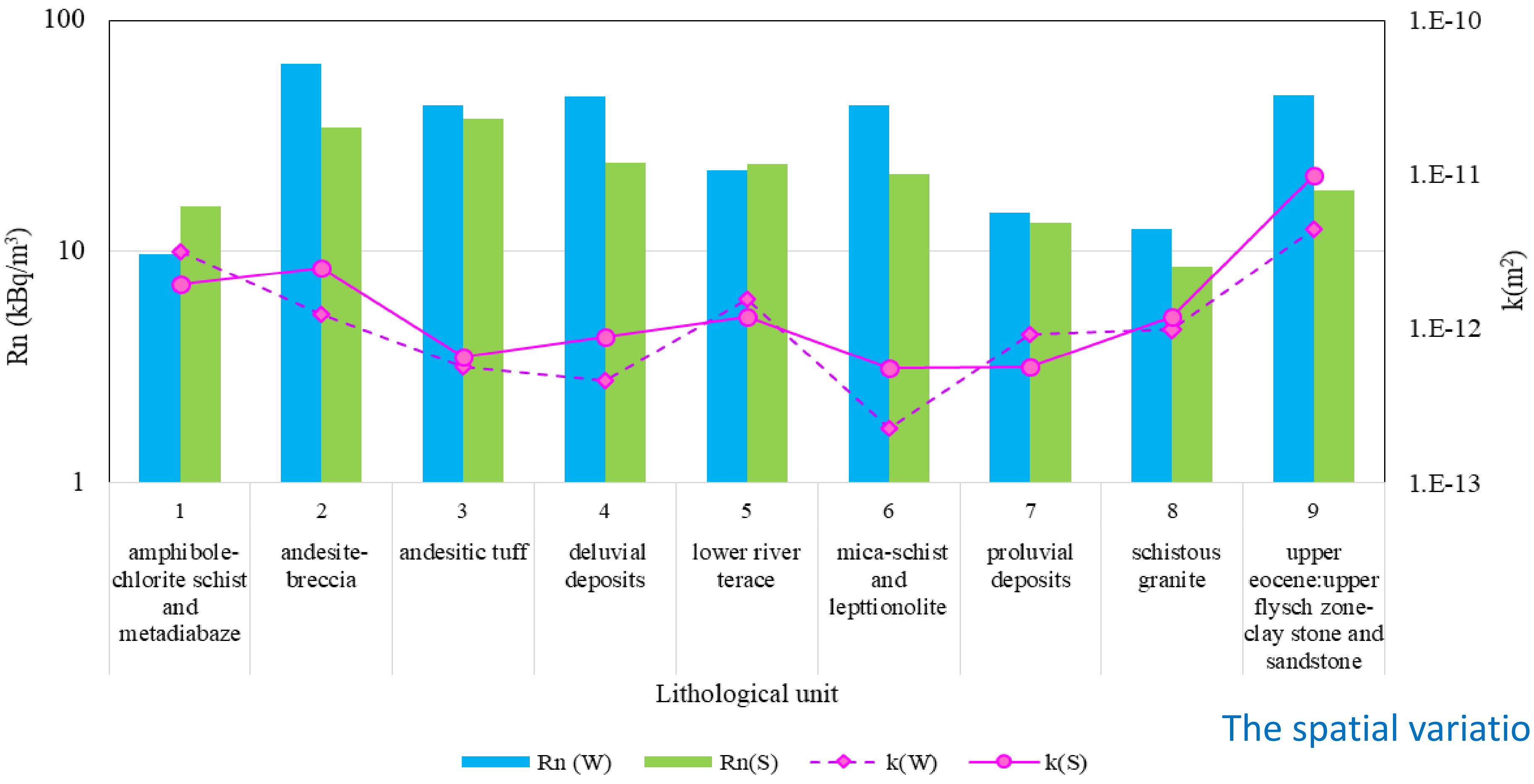


RP for both period

Results: Descriptive statistic

	winter			spring		
	Rn (kBq/m3)	k (1/m2)	RP	Rn (kBq/m3)	k (1/m2)	RP
No. of observations	29	29	29	29	29	29
Minimum	7	1.7E-13	2	8	2.5E-14	2
Maximum	84	7.8E-12	49	60	1.9E-11	38
Median	33	1.0E-12	18	24	1.4E-12	10
Arithmetic Mean	33	2.1E-12	18	24	3.3E-12	13
Standard deviation	20	2.1E-12	13	13	4.7E-12	8
CV	61%	102%	71%	56%	143%	62%
Geometric mean	27	1.2E-12	14	21	1.3E-12	11
Geometric standard deviation	2.00	3.02	2.18	1.76	4.51	1.91

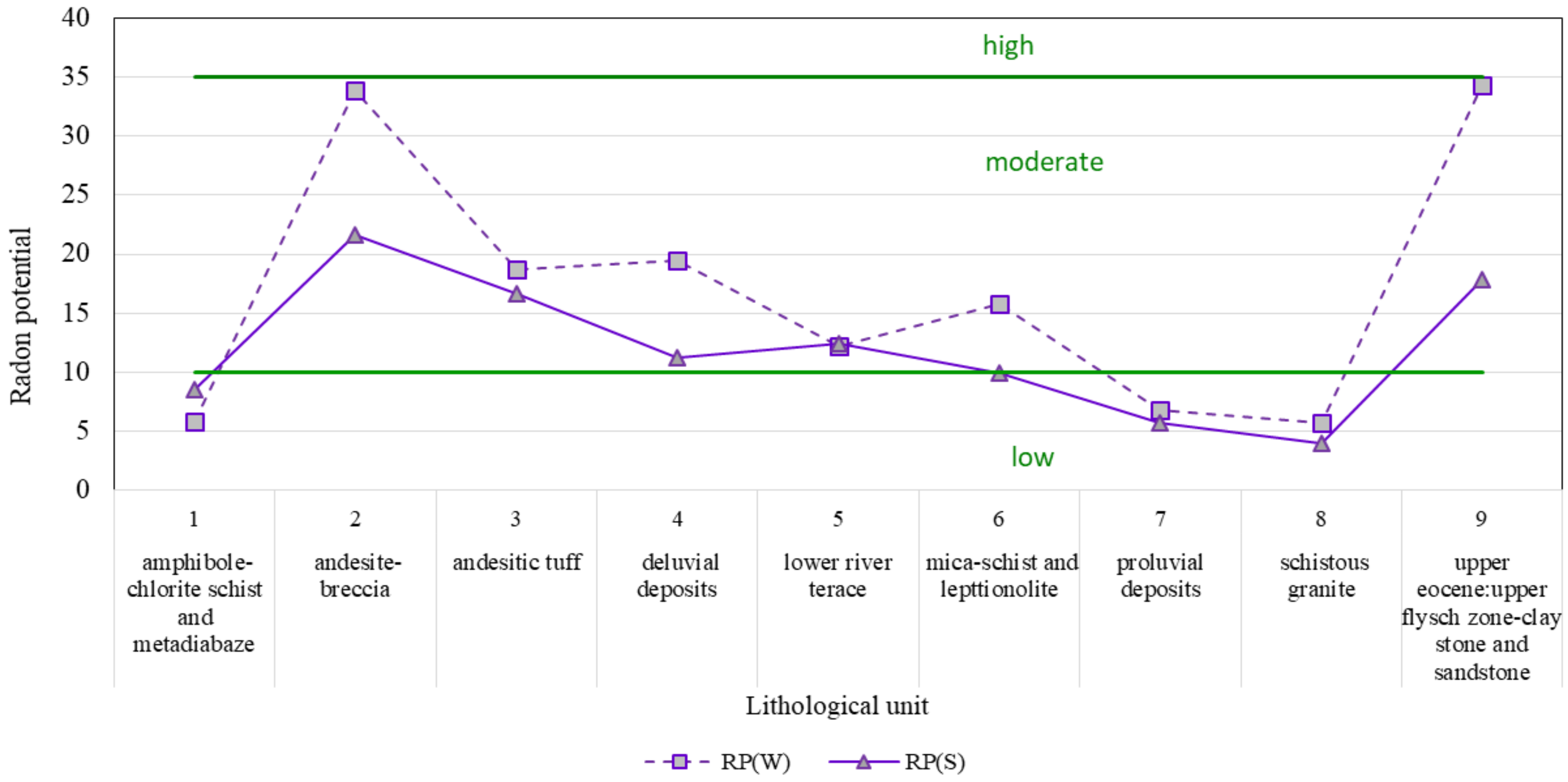
Results: Variations of measured quantities within lithological units



- Andesite breccia –the highest radon concentration in soil gas unit is represented by Granitic rocks
- Lithostratiological unit 9: is presented with unbound sedimentary rocks of the alluvial part of the investigated area. Under this rocks lie older magmatic and metamorphic rocks.

The spatial variation was significant only for Rn(W)

Results: Radon potential variation within lithological units

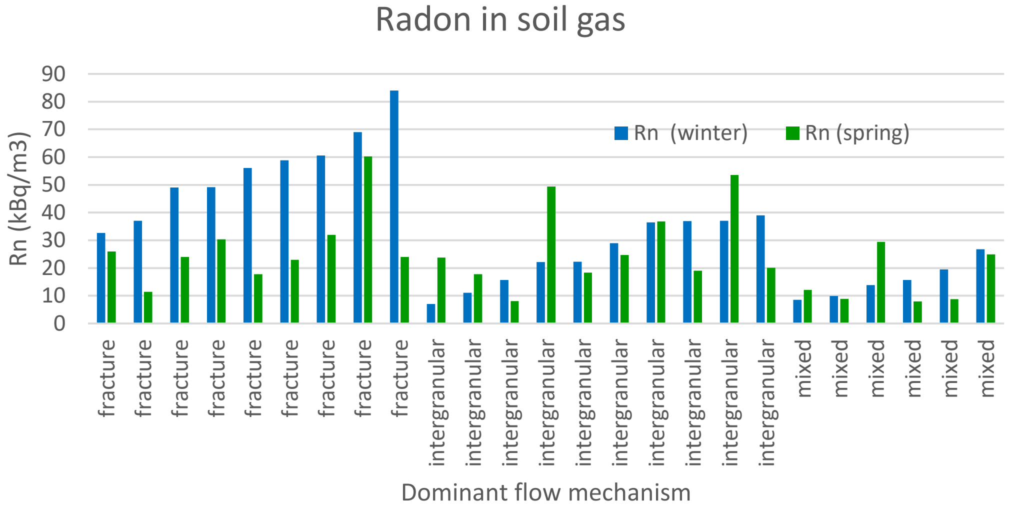


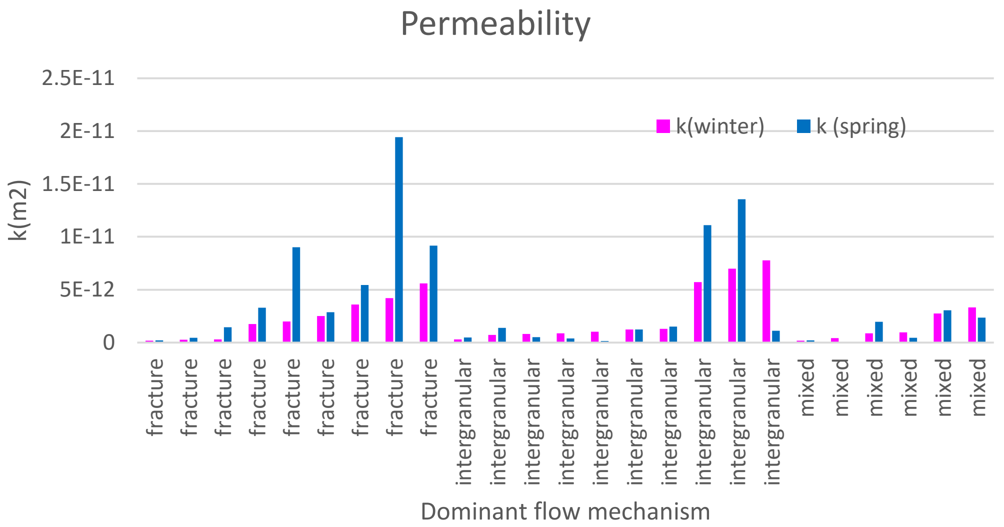
Statistical analysis have been shown:

The spatial variation was significant for RP(W) and RP (S)

The temporal variations were not significant

Measured results classified according to dominant flow mechanism in soil



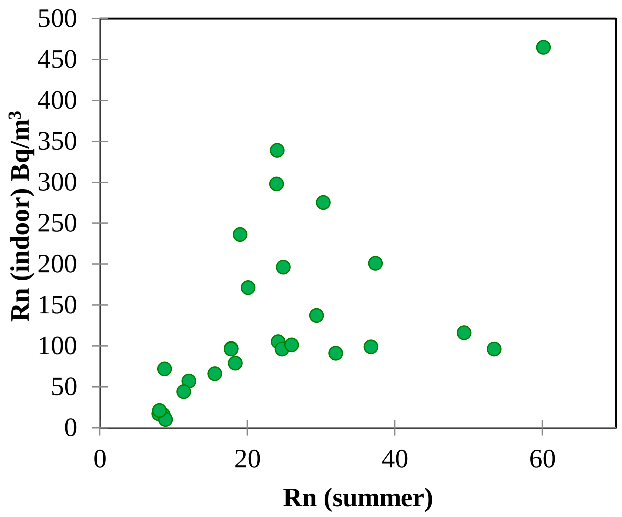


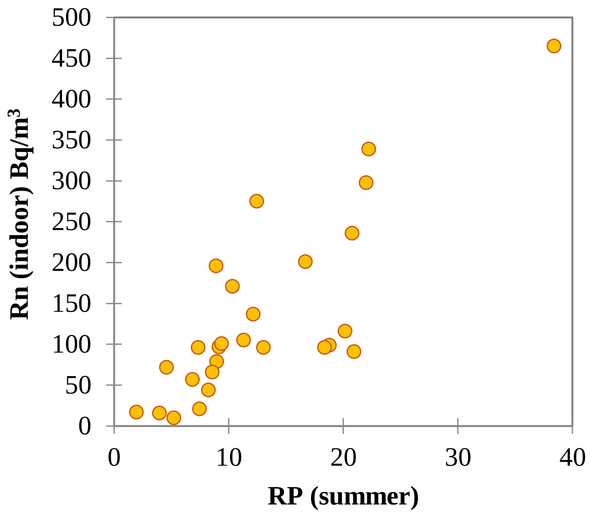
- Radon in soil gas concentrations measured in winter period in soil with fracture dominant mechanism were higher in comparison with soil where the dominant flow mechanism are: intergranular and mixed (intergranular and fracture);

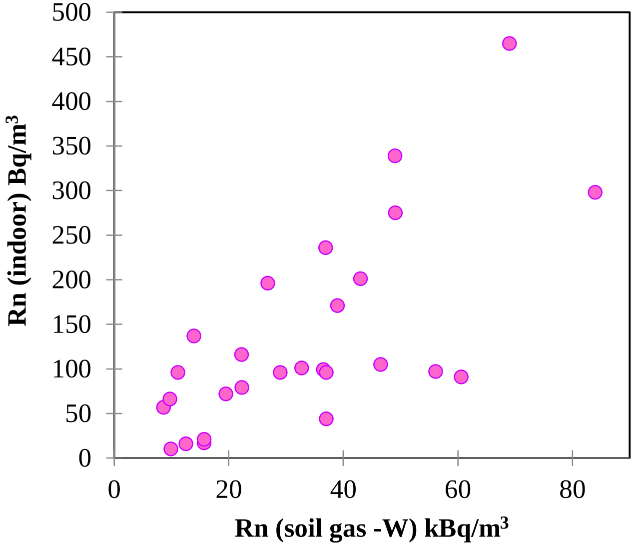
- Dominant flow mechanism not significantly affect permeability;

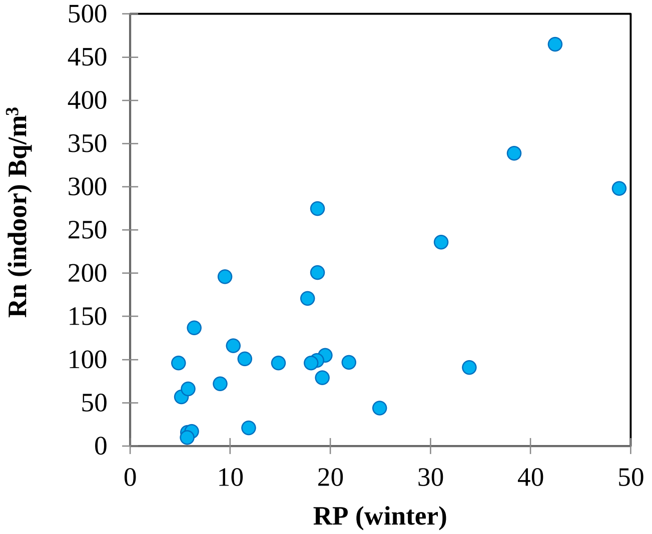
Correlations with indoor radon

Variables	Spearman correlation coefficients
Rn (indoor) vs Rn (winter)	**0.6679**
Rn (indoor) vs k(winter)	-0.2096
Rn (indoor) vs RP (winter)	**0.5858**
Rn (indoor) vs Rn (spring)	**0.6953**
Rn (indoor) vs k (spring)	-0.0367
Rn (indoor) vs RP (summer)	**0.7892**









Conclusion remarks(1)

- Temporal variations were significant only for concentrations of radon in soil. Variations in permeability were not significant.
  - For an explanation we highlight the following facts:
    - In January, the ground was saturated and the upper layer was frozen and covered with snow;
    - In June also the ground was saturated due to the permanent rainfall in the days prior to the measurements;
- Saturated soil in both periods explains no significant differences in permeability.
- Higher concentrations of radon in the winter to spring due to:
- The frozen layer of soil reduces radon exhalation into atmosphere

Conclusion (2)

- Spatial variability of permeability was not confirmed
- Radon concentrations measured in different lithostratological units was different-only for measurements in winter.
  - Rn measured in winter period in soil with fracture dominant mechanism were higher in comparison with soil where the dominant flow mechanism are: intergranular and mixed (intergranular and fracture); Fracture allow radon from great depths to be transported in the surface layers of the earth

Conclusion (3)

- The RP spatial variation was significant for both periods;
- The temporal variations were not significant ;
- The correlation between Indoor radon and RP obtained from both sets of measurements