FIELD INTERCOMPARISON MEASUREMENT OF SOIL-GAS RADON CONCENTRATION - PRACTICAL INTRODUCTION

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History of soil-gas radon concentration measurements

Badgastein, Austria, 1991

CLIFF, K. D. – HOLUB, R. F. – KNUTSON, E. O. – LETTNER, H. – SOLOMON, S. B. (1994): International intercomparison of measurements of radon and radon decay products, Badgastein, Austria, September, 29 - 30, 1991, published by National Radiological Protection Board, Chilton, Didcot, Oxon.

New York, U.S.A., 1995

HUTTER, A. R. – KNUTSON, E. O. (1998): An International intercomparison of soil gas radon and radon exhalation measurements, Health Physics, Vol. 74, pp. 108-114.

Prague, Czech Republic, 1996

NEZNAL, M. – NEZNAL, M. – ŠMARDA, J. (1997): Intercomparison measurement of soil-gas radon concentration, Radiation Protection Dosimetry, Vol. 72, pp. 139-144.

Buk (near Pribram), Czech Republic, 2002

NEZNAL, M. – NEZNAL, M. (2004): International intercomparison measurement of soil-gas radon concentration, of radon exhalation rate from building materials and of radon exhalation rate from the ground, in Radon investigations in the Czech Republic, edited by I. Barnet, M. Neznal and P. Pacherová (Czech Geological Survey and RADON v.o.s, Prague), Vol. 10, pp. 12-22.

Pribram (Buk, Cetyne, Bohostice), Czech Republic, 2010

MATOLÍN, M. – NEZNAL, M. – NEZNAL, M. (2012): International intercomparison measurement of soil-gas radon concentration (RIM 2010), of radon exhalation rate from building materials and of radon exhalation rate from the ground, 11th International Workshop on the Geological Aspects of Radon Risk Mapping (proceedings), edited by I. Barnet, M. Neznal and P. Pacherová (Czech Geological Survey and RADON v.o.s, Prague), pp. 166-173.

Sealices el Chico, Spain, 2011

GUTIÉRREZ-VILLANUEVA, J. L. et al. (2012): International intercomparison exercise on natural radiation measurements under field conditions, Saelices el Chico (Spain), May 2011, published by PUbliCan Editiones de la Universidad de Cantabria, Santander

Pribram (Buk, Bohostice), Czech Republic, 2012

Brazil 2014; Serbia 2014; Czech Republic 2014

EXPERIENCES (INTERCOMPARISONS 1991 – 2002):

⇨ **From the metrological point of view, there are many serious problems connected with organizing any field intercomparison measurement of soil-gas radon concentration and similar parameters. The natural geological environment is almost never homogeneous. Measured parameters may vary, often very greatly, over a small distance.**

⇨ **Comparison based of single values is almost worthless. Every participant should report a set of measured values.**

⇨ **All participants should measure the soil-gas radon concentration at the same depth below the ground surface.**

⇨ **Geological conditions in a depth of soil-gas sampling as well as conditions on the soil surface should be as homogeneous as possible at the test site.**

EXPERIENCES (INTERCOMPARISONS 1991 – 2002):

⇨ **„Classical“ field intercomparison measurements are not intended to be used as an intercalibration of methods and instruments. Measured values are not reported against a standard or reference measurement. Participants results are compared to each other, in order to obtain an indication of the collective precision of various measurements.**

⇨ **Incidence of outsider values may strongly influnce the results of the intercomparison measurement.**

⇨ **Differences connected with primary calibration are usually lower than 10 percent.**

⇨ **Differences on the level of about 20% seem to be a realistic target for intercomparison measurements of soil-gas radon concentration. If the variability is much larger than 20%, problems with soil-gas sampling and/or with primary calibration are indicated.**

EXPERIENCES (INTERCOMPARISONS 1991 – 2002):

⇨ **Frequent systematic failures are connected with soil-gas sampling.** **If the sampling system is not sealed perfectly, the soil-gas samples are „contaminated“ by the atmospheric air. The real soil-gas radon concentrations are then underestimated. For testing the applicability of sampling methods, it is useful to choose a test site characterized by medium, or low permeability of soil.**

Another cause of the dilution of soil-gas by the atmospheric air is a too large volume of the soil-gas sample. The capacity of the soil-gas in the soil is not unlimited.

⇨ **Preliminary measurements should be limited at a chosen test site to avoid a destruction of the upper soil layers (the upper soil layers should not remind of a Swiss cheese). This is very important if radon exhalation from the ground surface is measured at the same test site.**

SYSTEM OF SOIL-GAS RADON DATA STANDARDIZATION IN THE CZECH REPUBLIC

about 100 institutions (mostly private firms) dealing with the determination of radon index of building sites (= measurement of soil-gas radon concentration and classification of permeability of soil)

each subject

⇨ **has to pass the training course „Determination of radon index of building sites“**

⇨ **has to pass the intercomparison measurement of soil-gas radon concentration at three field radon reference sites**

administrator: Charles University in Prague, Faculty of Science; 3 different levels of soil-gas radon concentration

⇨ **has to verify regularly all measurement devices for the determination of soil-gas radon concentration in radon chamber**

⇨ **has to get the authorization from the State Office for Nuclear Safety**

The procedure was used in the last two soil-gas radon international intercomparison exercises in the Czech Republic (2010, 2012).

This approach represents a step from a „classical“ field intercomparison measurement to a standardization.

SYSTEM OF RADON DATA STANDARDIZATION IN THE CZECH REPUBLIC

National radon chamber:
(Located in Příbram)

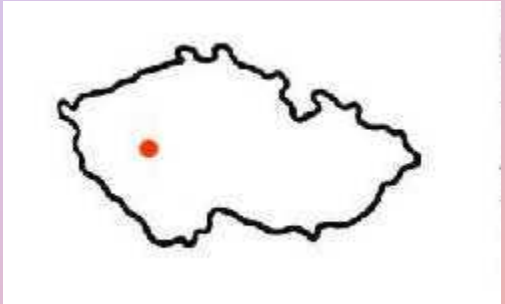
- Verification of instrument, its function, sensibility and calibration,
- Verification of data processing.

National radon chamber was levelled with PTB Braunschweig, GER

Radon reference sites:
(Located in the central Bohemia)

- Test of soil gas sampling,
- Transfer of soil gas sample and its timing,
- Test of the radon instrument and its function,
- Elimination of thoron,
- Stability of field operation,
- Test of correct data processing.

CHARACTERISTICS OF RADON REFERENCE SITES, CZECH REPUBLIC



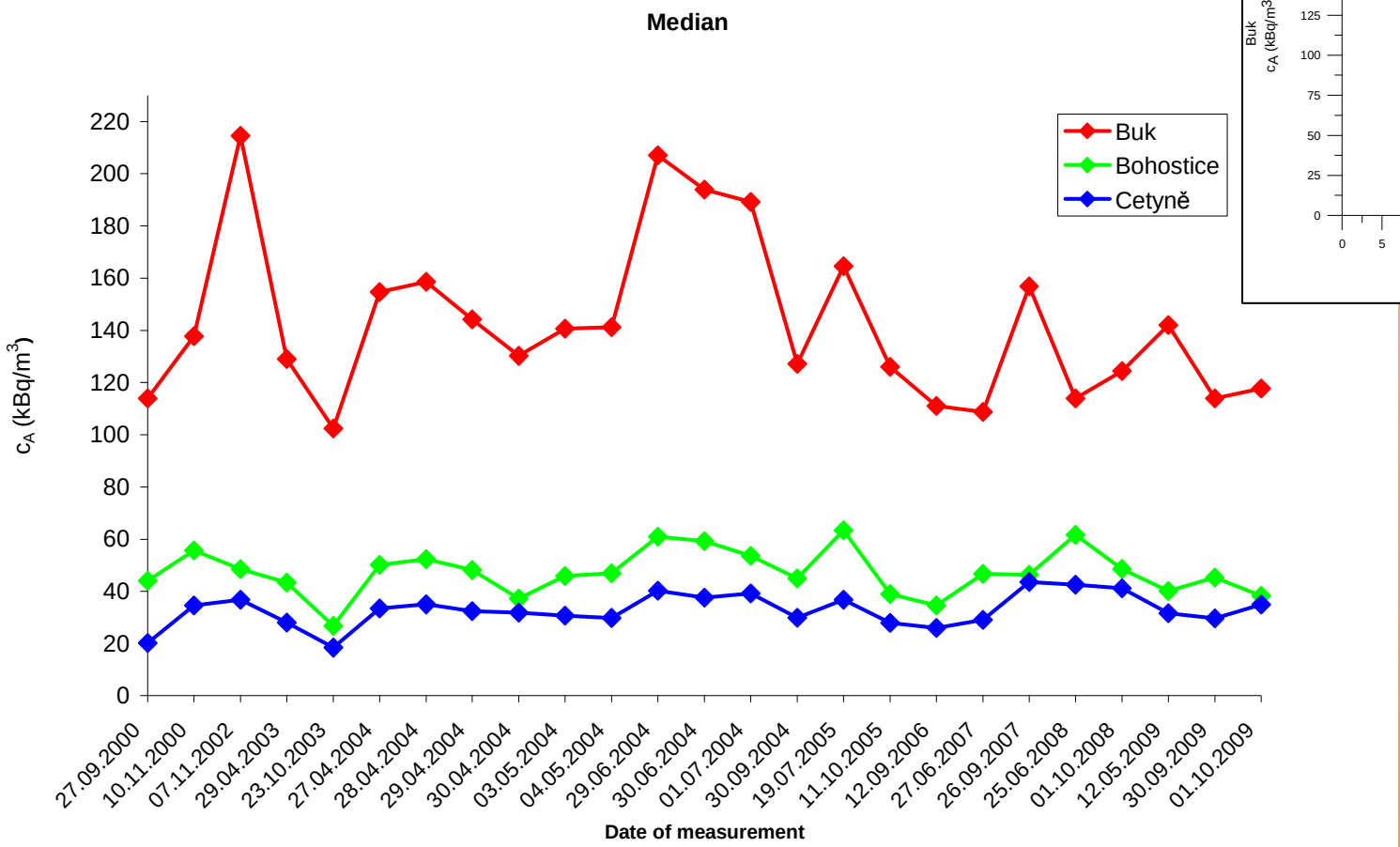
Radon reference sites

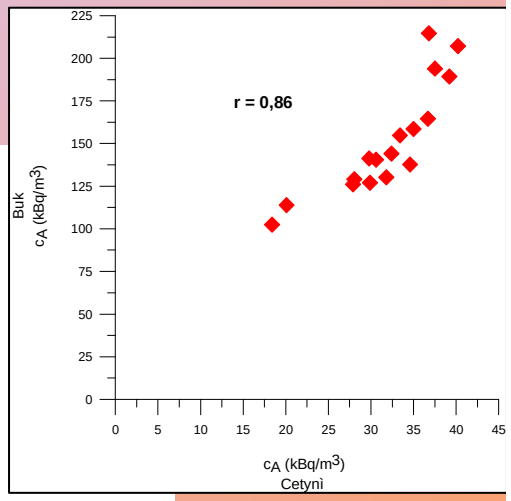
Number of stations at each site: 15
Grid of stations: 5x5 m
Distance of the 3 reference sites: 12 km

Reference site	c_A ^{222}Rn (kBq/m^3)	Permeab. of soil	Basement rock	Soil	U (ppm)	Terrain	Access for cars
Cetyne	32	L,(M),H	orthogneiss	SL	2.0	meadow	+
Bohostice	52	(L),(M),H	orthogneiss	LS,CS	2.3	meadow	+
Buk	155	H	granodiorite	LS	3.6	meadow	+

Charles University in Prague

TEMPORAL VARIATIONS OF RADON IN SOIL GAS AT REFERENCE SITES 2000 - 2009





Temporal variations of radon activity concentration in soil gas at reference sites Cetyne, Bohostice and Buk, the Czech Republic.

TESTS AT RADON REFERENCE SITES

Computer programme TestMOAR

Test 1

Comparison with the group

Test 2

Comparison with the group

Charles University in Prague

Charles University in Prague, Faculty of Science
Institute of Hydrogeology, Engineering Geology and Applied Geophysics
Department of Applied Geophysics
128 43 Praha 2, Albertov 6

Assessment of comparison measurement of Rn-222 activity concentration in soil air at reference sites Cetyně, Bohostice and Buk.

Organization: AAA
Street and No.
City/village, postal code

Date of measurement: 10. September 2000

Used symbols: c_A - radon activity concentration in soil air, (kBq/m^3)
t - argument of Student´s distribution

Test 1 - test of differences in c_A measured by organizations at single reference sites

The difference between c_A measured by given organization at single observation points of a reference site and median of c_A data determined by other organizations, including the administrator, at relevant observation points, in the same day, is tested. The difference is significant, if the calculated interval of confidence does not imply zero.

Reference site	*Interval of confidence*	*Ratio of data outside the interval of confidence*
Cetyně	< -5.963; 11.449 >	4/15
Bohostice	< -11.165; 4.912 >	1/15
Buk	< -1.541; 9.701 >	2/15

Test 2 - linear regression and correlation of c_A data measured in the same day at reference sites

Dependence of c_A data measured by given organization (y) on medians (x) of c_A data determined by other organizations, including the administrator, at relevant observations points, in the same day, is expressed by linear regression $y = a + bx$. In ideal case of data coincidence is $a = 0$, $b = 1$. The data acceptable coincidence is not proved, if the calculated t-value of the test criterion exceeds the critical t-value.

Regression parameter	*Calculated t-value*	*Critical t-value*	*Coefficient of correlation*
a = -0.486	0.181	2.695	0.984
b = 1.022	0.788	2.695	

TESTS AT RADON REFERENCE SITES

Test 3

Comparison with the radon database

Testing criterion R1/R2 of an ideal value equal to one and acceptable deviations +/- 30 %; R1/R2 <0.7 – 1.3>

Test 3 - comparison of c_A data of an organization with all available c_A data from the reference site, under elimination of radon temporal variations and the level of c_A data of the administrator

Radon activity concentration in soil air at each single reference site is tested by means of a ratio of two parameters R1 and R2. Parameter R1 is the ratio of the c_A mean at the reference site, reported by the organization, to c_A mean, reported by the administrator. Parameter R2 is the average of all available R1 data of preceding measurements at the given reference site. Testing criterion R1/R2 compares the c_A data, reported by the organization, with c_A data of preceding measurements of all organizations. Acceptable deviation from ideal value R1/R2 = 1 is 30 % relatively, R1/R2 < 0.7; 1.3 >.

Reference site	*Parameter R1*	*Ratio R1/R2*
Cetyně	1.050	1.084
Bohostice	0.865	0.917
Buk	0.993	1.018

Ideal value is 1.000

Conclusions

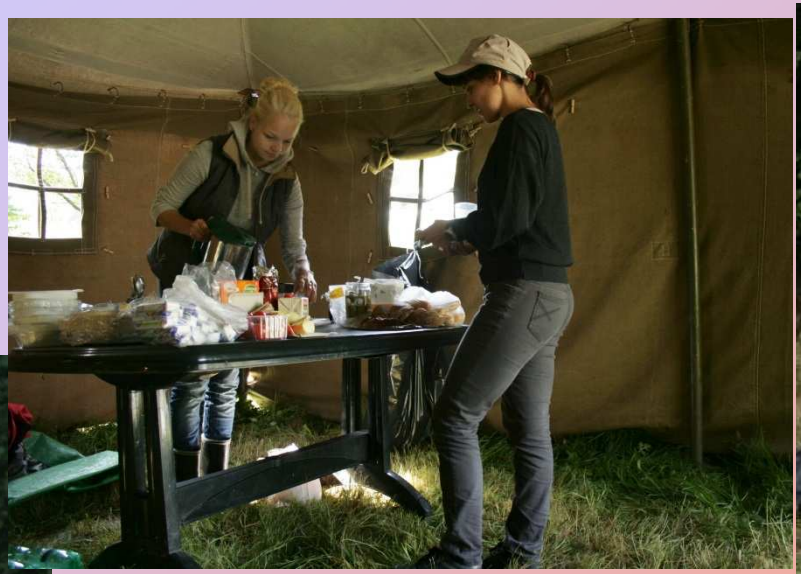
Test 1 and test 2 (both orientative) indicate general coincidence between radon concentration activity reported by your organization and the data reported by organizations participating in the test on the same day. Test 3 shows an agreement of your data with the data of all organizations tested at the reference sites since the year 2000. The procedure of radon in soil air determination, applied by your organization, can be used for radon risk mapping at building sites after the Act No. 18/2002, and the relevant Decree of the State Office for Nuclear Safety No. 184.

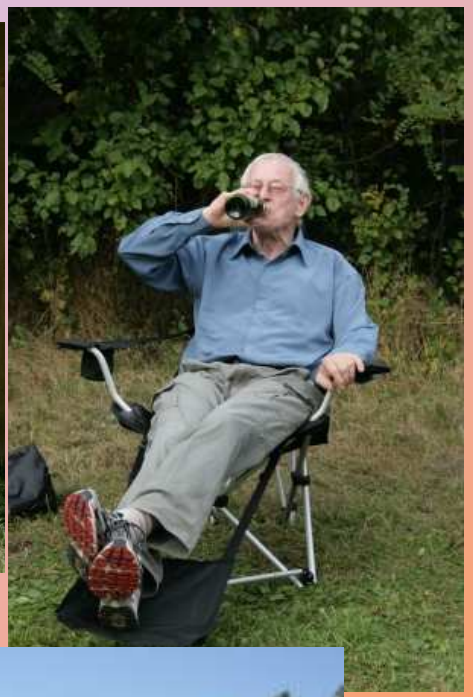
Datum

Signature

Seal

RIM 2010, 2012





RIM 2010

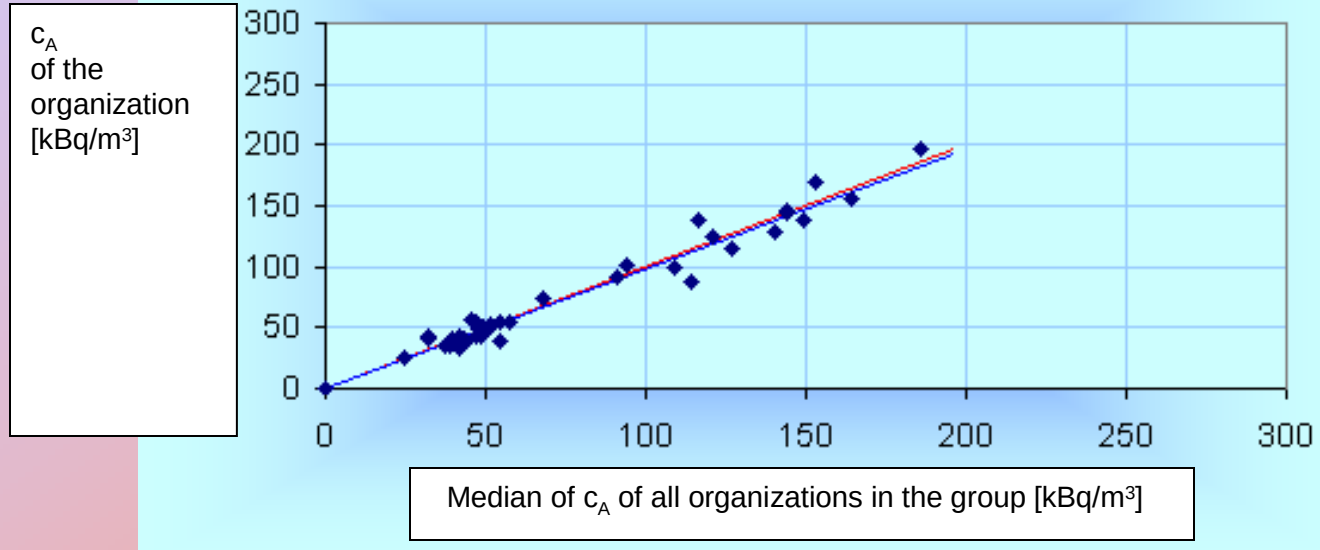
Results - example

Test No. 2: Linear regression y = a + bx of radon activity concentration reported by an organization (y) at a single station and median (x) of radon activity concentration of the group of organizations at the same station. An ideal data agreement is a = 0, and b = 1. This presumption is rejected if computed t-value is larger than critical t-value. Level of significance α = 1 %.

Tested by Computer programme TestMOAR.

Example of excellent agreement between radon data of an organization and medians of radon data of the group of organizations.

Test 2 – linear regression y = a + bx (blue) between radon activity concentration c_A reported by the organization (y) and medians of c_A (x) of all organizations in the group. Ideal regression line (a = 0, b = 1) is marked red.



a	=	0,599	ta	=	0,236
b	=	0,984	tb	=	0,542
r	=	0,982	tkrit	=	**2,695**

RIM 2010

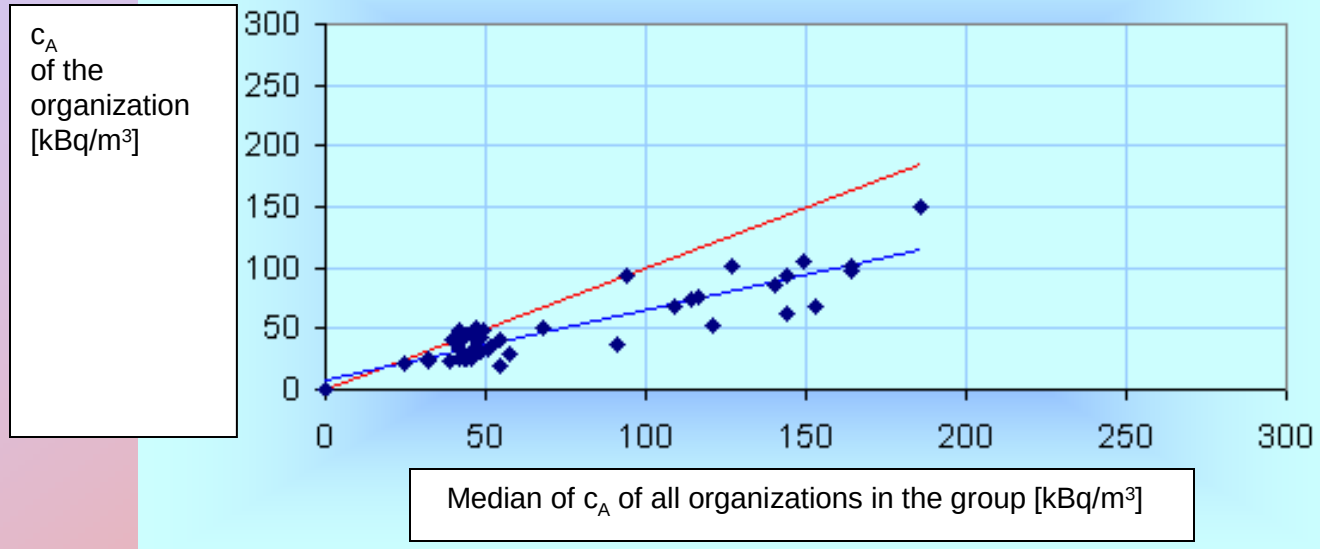
Results - example

Test No. 2: Linear regression y = a + bx of radon activity concentration reported by an organization (y) at a single station and median (x) of radon activity concentration of the group of organizations at the same station. An ideal data agreement is a = 0, and b = 1. This presumption is rejected if computed t-value is larger than critical t-value. Level of significance α = 1 %.

Tested by Computer programme TestMOAR.

Example of poor agreement between radon data of an organization and medians of radon data of the group of organizations.

Test 2 – linear regression y = a + bx (blue) between radon activity concentration c_A reported by the organization (y) and medians of c_A (x) of all organizations in the group. Ideal regression line (a = 0, b = 1) is marked red.



a	=	8,389	ta	=	2,150
b	=	0,570	tb	=	9,645
r	=	0,891	tkrit	=	**2,695**

RIM 2010

Results - example

Test No. 3: Comparison of average (AM) radon activity concentration in soil gas at radon reference sites

Normed radon data R1/R2
Criterion R1/R2 ideal value 1.0, acceptable range (0.7; 1.3)
Criterion R1/R2 is applicable for each single reference site

Tested by Computer programme TestMOAR

	Reference site			
	Cetyne	Bohostice	Buk	
Organization	Criterion R1/R2			Average R1/R2
A02	1,135	1,075	1,015	1,075
A03	1,108	1,041	1,275	1,141
A04	1,055	1,021	1,094	1,057
A05	0,795	0,725	0,722	0,747
A06	1,230		0,990	1,110
A07	0,834	0,688	0,662	0,728
A08	1,162	1,023	1,410	1,198
A09	1,094	0,872	1,072	1,013
A10	0,960	0,990	1,041	0,997
A11	0,986		1,021	1,004
A12	1,026	0,970	1,012	1,003
A13	1,482		1,360	1,421

INTERCOMPARISON MEASUREMENT

SERBIA 2014

Preliminary measurements were performed by RADON v.o.s. in October 2013:
Choice of an appropriate test site.

Niška Banja:
Area „Šljive“

15 measuring points (grid 5 x 5 m)

recommended sampling depth: 0.8 m

Thank you