12th International Workshop on the Geological Aspects of Radon Risk Mapping
Prague, September 2014

IRART PROJECT: SOME FINDINGS AND CONCLUSIONS REGARDING RADON EXPOSURE AND MITIGATION IN BAITA-STEI AREA, ROMANIA

C. Cosma, A. Cucos (Dinu), B. Papp, T. Dicu, M. Moldovan, B. Burghele, D. Nita, R. Begy, O. Dumitru, C. Sainz*

Babeк-Bolyai University, Cluj-Napoca, Romania
***Cantabria University, Santander, Spain**

with participation of: Martin and Matej Neznal (houses investigations)
Andre Poffijn (final evaluator)

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EUROPEAN FOUND (83%) + National Found (17%)

2.1.2: High R-D Projects with European research participation

IMPLEMENTATION OF RADON REMEDIALTEHNIQUES IN HOUSES FROM BAITA URANIUM MINE ZONE (IRART)

Project POS CCE ID 586 - SMIS 12487/ 160/ 15.06.2010

during the period 15 IUNIE 2010 - 15 IUNIE 2013

Project Director: **Prof. Dr. Carlos SAINZ,**

Manager Project: Prof. Dr. Constantin COSMA

Responsible of project: **Dr. Ing. Alexandra DINU (CUCOS)**

IRART

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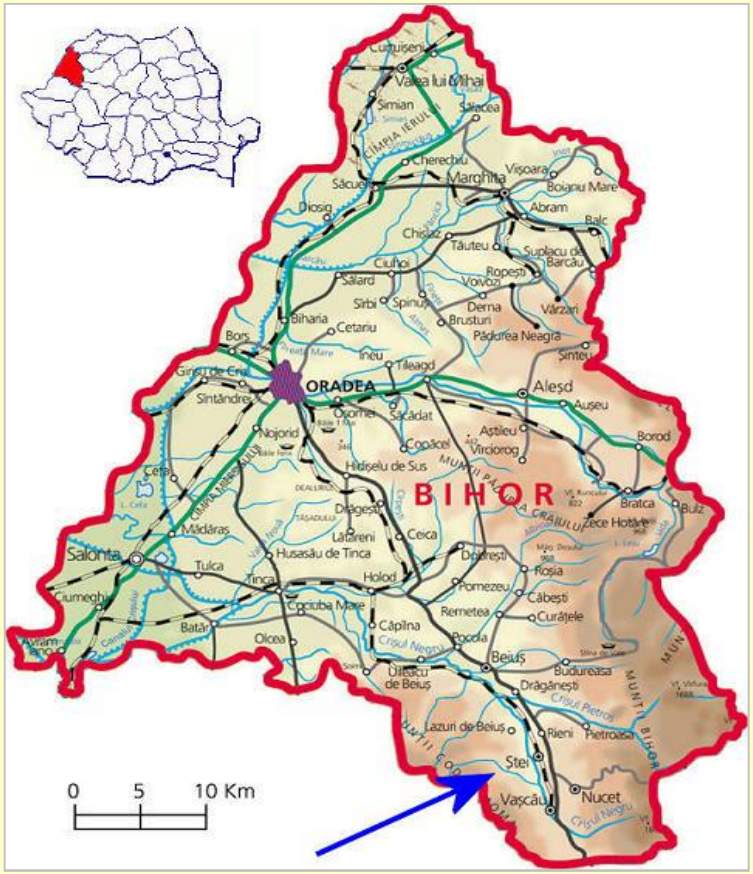
BAITA URANIUM MINE

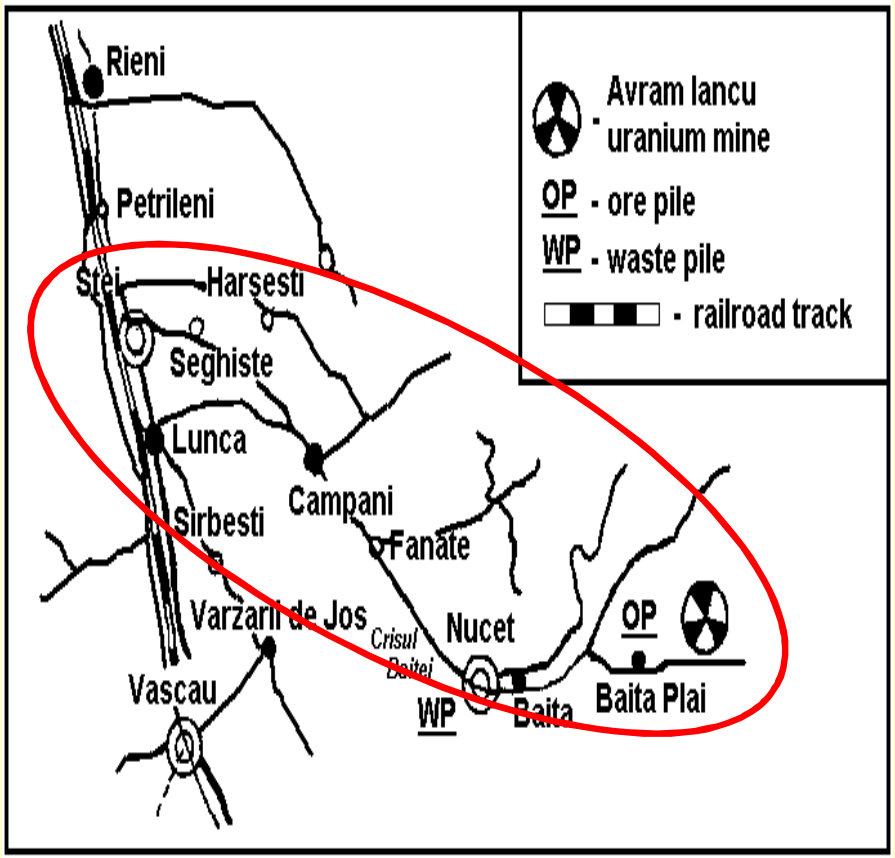
the largest surface uranium deposit in the world (open pit mine)

20,000 tones of Uranium were extracted (Photo and satellite view)

Baita-Stei area: is situated in **Bihor country -** northwest of Romania at 120 km southeast of Oradea and 2-8 km downstream of the river Cris



Romania /Bihor map and Baita-Stei zone

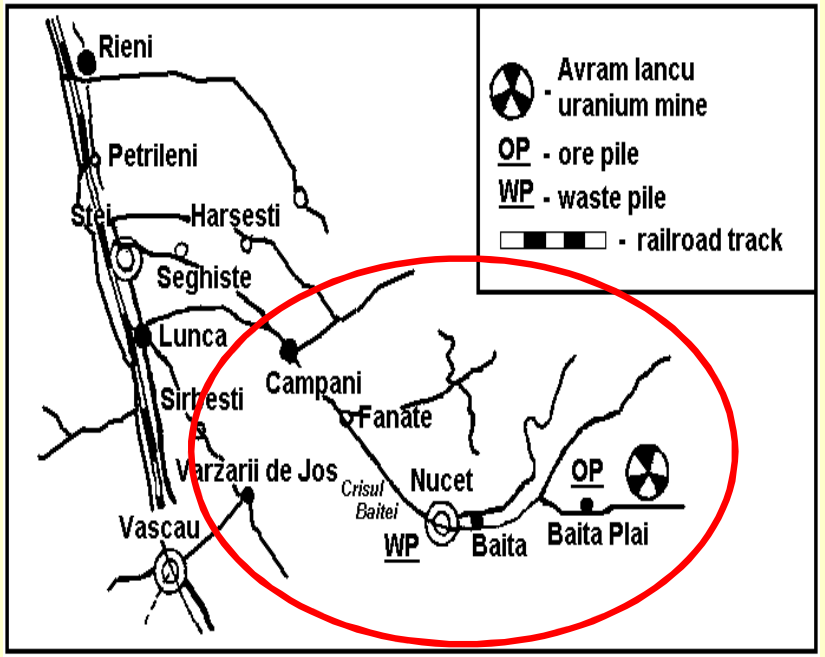


Investigated Baita-Stei area

Romanian-Spanish- Czech team participating in IRART Project
Open remedial actions: Radon sources identification in each house

Indoor measurements and selection of the houses for remediation

- integrated measurements (CR 39 track detectors)
- 2 campaigns of measurements (W-2010, Sp- 2011)
- 303 randomly selected houses from 800 (total)
- 3-4 rooms/house
- 2300 measurements (2x1150)



$$C_a = C_m \cdot [(n_{Sp,A}/n) + r \cdot (n_{S,W}/n)]$$

where, C_m = measured concentration,

n_{Sp}, n_A, n_S, n_W = month nr. In each season

r = factor for correcting exposure:

(r(W)=0.67; r(S)=1.35).

[Cosma et al., 2009, IEHS]

Descriptive statistics of the radon measurements results in dwellings of BŁiŞa-Stei area.

Room type	Freq.	AM ± SD (Bq m^{-3})	GM ± GSD (Bq m^{-3})	Median (Bq m^{-3})	Max (Bq m^{-3})	C.V. (%)
Kitchen	247	196 ± 191	141.3 ± 2.2	131	1278	98
Bedroom or Living	618	273 ± 253	197.1 ± 2.2	196	2016	91
Cellar *	233	251 ± 343	151.8 ± 2.5	136	3054	137
Other	30	188 ± 161	133.2 ± 2.4	135	651	86

Note: GM ≈ Median ⇒ log-normal distribution

****Because of a light winter the majority of cellars was open to outdoor***

Results for selected houses (20): winter, spring and annual mean [Bq/mc]

Adress	RP	Room	Winter	Sring	Annual mean
B. Iŝ A 6	119	bedroom	1461	1613	1296
B. Iŝ A 75	148	bedroom	1406	909	926
B. Iŝ A 76	99	living room	1452	1188	1080
B. Iŝ A 119	85	bedroom	1353	508	707
B. Iŝ A 138	75	living room	901	902	753
B. Iŝ A 204	123	bedroom	1025	774	730
B. Iŝ A 206	79	living room	3092	1772	1922
B. Iŝ A 213	136	bedroom	1587	1219	1141
B. Iŝ A 215	66	bedroom	1357	1002	956
BAITA 127	-	living room	1560	912	903
B. Iŝ A 228	93	living room	1354	1277	1092
CÂMPANI 57	62	bedroom	1013	301	490
CÂMPANI 71	159	bedroom	751	537	520
CÂMPANI 103	51	bedroom	869	468	525
FÂNAŝ E 23	163	kitchen	1950	1206	1256
FÂNAŝ E 189	192	bedroom	1392	623	778
FÂNAŝ E 118	21	bedroom	1446	1169	1069
FÂNAŝ E 136	40	bedroom	1600	1590	1395
FÂNAŝ E 59	-	bedroom	1451	1266	1177
NUCET 9	66	bedroom	2610	-	1958

The main mitigation tehniques:

- ***Subsoil depressurization***
- ***Sub-slab and subsoil extraction***
- ***Membrane installing***
- ***Sub-slab ventilation***
- ***Remove stones with high uranium content***

Efficiency of Remediaton: $Eff. = (C_i - C_f) / C_i$

where C_i ***and*** C_f ***are the annual integrated radon concentration before and after remediation***

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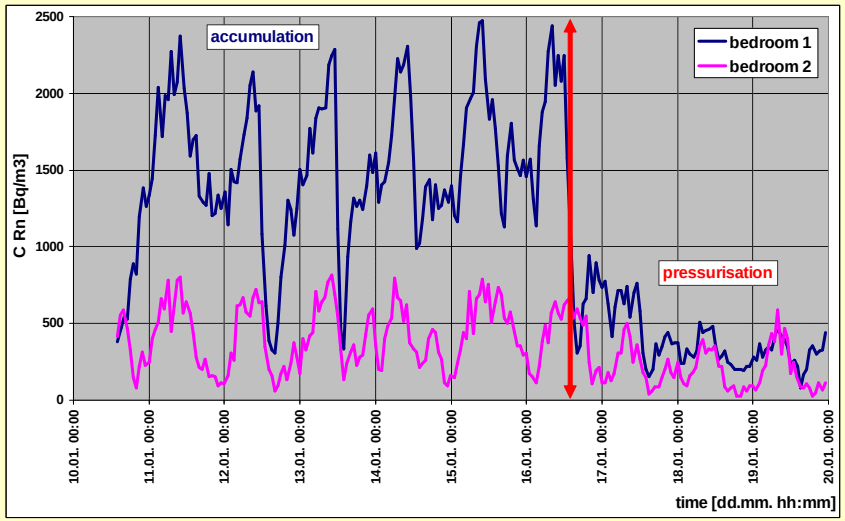
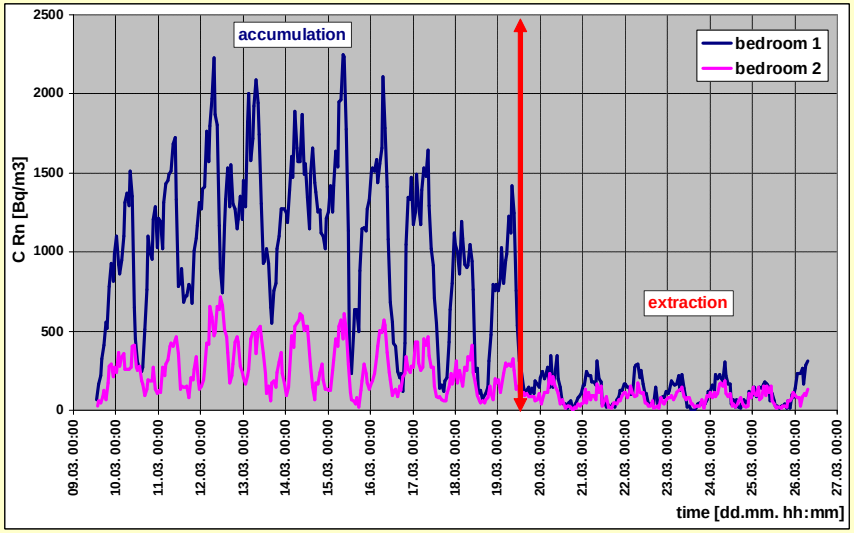
Subsoil depressurization

Sub-slab and subsoil extraction

Sub-slab ventilation





Membrane installing

Eolian (Wind) Extraction

Remove stones with high U content, from the house walls

A piece of stone taken from the cellar wall

Measured by gamma spectrometry

(U conc. 34%) !!

Efficiency of remediation 2012

Nr.	House adress	Room	Annual CRn (Bq/m3)		Eff* (%)	Mean Eff. all rooms (%)	Var of Eff. (%)
			Before	After			
1.	Baita 6	bedroom	1354	159	88.3	*79.0*	*71.1 - 88.3*
2.	Baita 75 A	bedroom	982	143	85.4	*85.3*	*85.3 - 85.4*
3.	Baita 75 B	Living	872	107	87.7	*87.7*	*87.7*
4.	BŁiŞa 76	Living	1062	100	90.6	*89.5*	*88.3 - 90.6*
5.	Baita 119	Bedroom	761	137	82.0	*84.5*	*80.5 - 82*
6.	BŁiŞa 127	Bedroom	948	92	90.3	*90.3*	*90.3*
7.	Baita 138	Bedroom	534	113	78.8	*78.8*	*65.6*
8.	BŁiŞa 204	Living	771	152	80.4	*78.3*	*75.9 - 80.4*
9.	Baita 206	Bedroom	1557	91	94.2	*93*	*83.5-94.2*
10.	Baita 213	Bedroom	1205	112	90.7	*79.1*	*67.5-90.7*
11.	Baita 215	Bedroom	1010	117	88.4	*81.9*	*75.5-88.4*
12.	Baita 228	Bedroom	1059	155	85.3	*86.4*	*79.1 - 85.3*
13.	Campani 57	Bedroom	530	91	82.8	*82.8*	*82.8*
14.	Campani 71	Bedroom	548	86	84.3	*77.0*	*72.6 - 84.3*
15.	Câmpani 103	Living	560	122	78.2	*78.2*	*78.2*
16.	FânaŞe 23	Kitchen*	3389	867	74.4	*70.6*	*66.7 - 74.4*
17.	FânaŞe 59	Bedroom*	1177	214	81.8	*65.2*	*65.4 - 81.8*
18.	Fanate 118	Bedroom	1127	77	93.2	*90.8*	*88.4-93.2*
19.	Fanate 189	Bedroom	834	219	73.7	*72*	*70.3-73.7*
20.	Nucet 9	Bedroom	1958	96	95.1	*95.1*	*95.1*
21	Pilot house	Bedroom	1395	174	87.5	*76.9*	*68.7-87.5*

** the room with the best efficiency (from house)*

Final results: - room with best efficiency: **85.4% (73.7- 95.1%)**
- all average rooms: **81.4% (65.2 - 95.1%)**

Comparison: - remedial efficiency in RADPAR Project (2012) by different methods

	Reduction factor (%), Typ. range								
Method	**Summary**	AT	BE	CZ	FI	FR	NO	CH	UK
Sub-slab depressurization	**60-95**	80	90	85-95	65-95	89	50-95	90	89
Improving natural ventilation in living spaces	**10-50**			< 30	15-55	49	10-50		33
Improving mechanical ventilation in living spaces	**10-60**				5-55	61	10-20		
Replacing the existing natural room air ventilation by a mech. exhaust ventilation	**10-40**				15-45		10-20		
Installation of a new mech. supply and exhaust ventilation with heat recovery system	**30-60**	60		30-60	30-65		10-80		
Improving ventilation in cellar	**20-60**	50		25-50	20-55	47	10-50	75	
Decreasing under-pressure in the house	**20-70**	50					10-50	25	60
Sealing entry routes	**10-60**	10		10-40	10-55	55	10-60	25	41
Improving crawl space ventilation	**40-60**	50			40-65	47	10-80	75	47

1. Remedial verification in winter 2013/2014

Adress	Annual mean Before and after Remediation		Continuous measurements winter 2014(2 wks)		Eff. 2014	Eff. 2012
	CR-39 2011	CR-39 2014	System no working	System working	%	%
BAITA 6	1296	91	360	71	80.2	79.0
BAIŝ A 75	926		1620	490	74.1	85.3
BAIŝ A 76	1080		1469	165	88.1	89.5
BAIŝ A 119	707	210	660	210	68	82
BAIŝ A 138	753	167	470	167	64.5	78.8
BAIŝ A 204	730		830	110	87.5	78.3
BAIŝ A 206	1922	205	830	110	86.7	93.0
BAIŝ A 213	1141		1250	?	-	79.1
BAIŝ A 215	956		860	162	81.6	81.9
BAITA 127	903		1460	240	83.6	90.3
BAIŝ A 228	1092		890	245	73.0	86.4
CAMPANI 57	490	62	835	104	87.5	82.8
CAMPANI 71	520		505	81	83.9	77.0
CAMPANI 103	525		800	200	75.0	78.2
FANAŝ E 23	1256		790	107	86.4	70.6
FANAŝ E 189	778		890	70	78.1	76.0
FANAŝ E 118	1069		898	155	82.7	90.8
FANAŝ E 136	1931	128	760	240	68.4	78
FANAŝ E 59	1177	118	790	310	60.7	65.2
NUCET 9	1958	77	1305	71	94.6	95.1
Average	**1060**	**122**	**914**	**182**	**79.1**	**81.4**

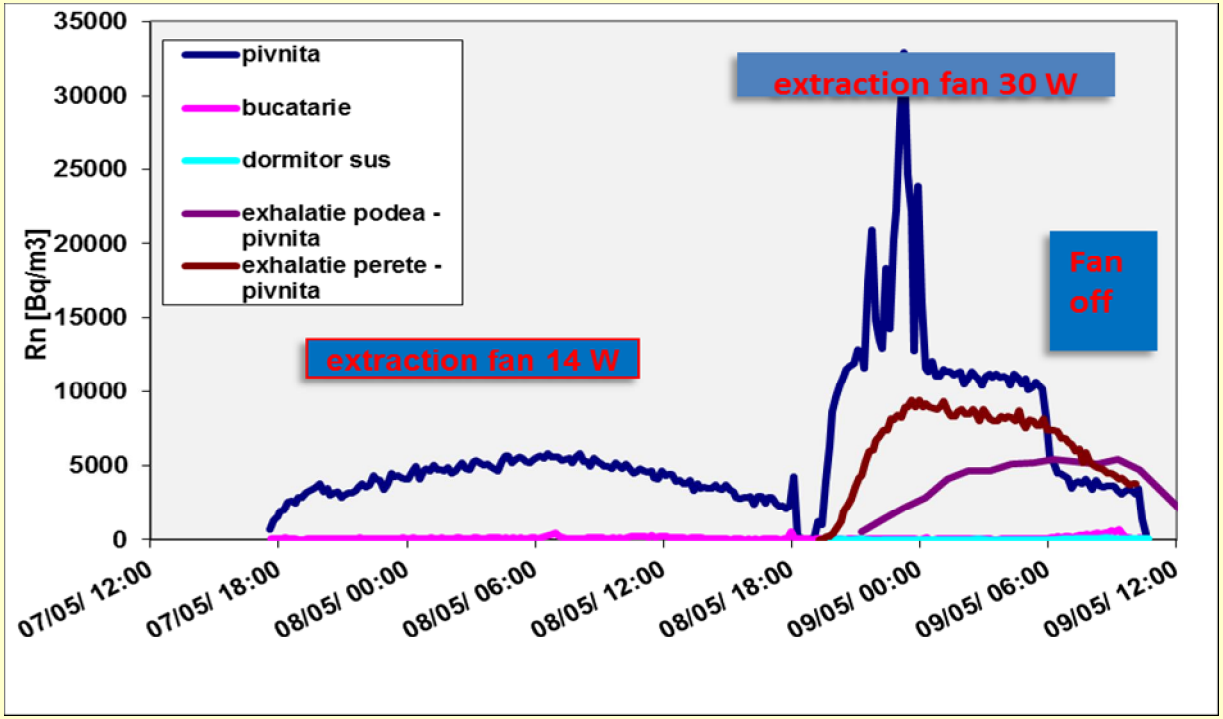
2. Efficiency Verification by wind extraction
(17 houses and 25 rooms)

Adress	Baita 6	BŁiŞa 75A	BŁiŞa 75 B	BŁiŞa 76	BŁiŞa 119	BŁiŞa 127	BŁiŞa 138	BŁiŞa 204	BŁiŞa 206
Room 1	74	44	80	2	18	38	40	-	87
Room 2	78	-	-	60	22	-	-	3	72

Adress	Baita 213	Baita 215	Baita 228	Cam 57	Cam 71	Cam 103	Fan 23	Fan 118	Fan 189
Room 1	38	7	85	78	18	53	45	74	83
Room 2		-	73	-	22	-	-	-	88

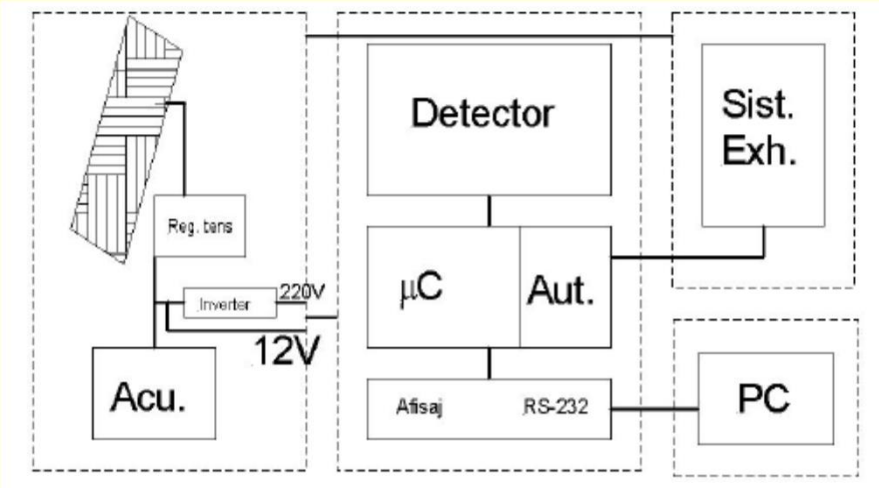
Average value 47,4% (2 ï 87%)

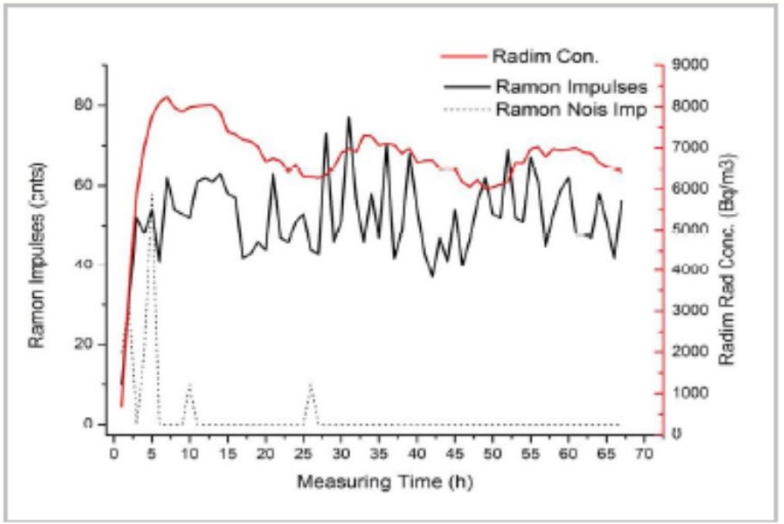
3. Influence of depressurization (rate of ventilation) on radon exhalation



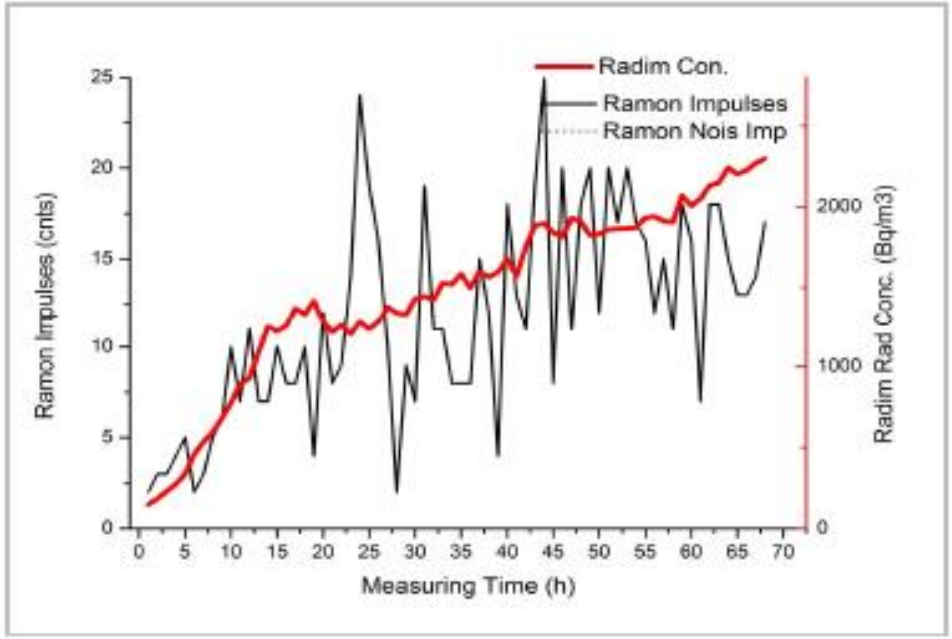
Power fan	Fan 14 W		Fan 30 W			Fan off		
Room	cellar	kitchen	cellar	kitchen	room above cellar	cellar	kitchen	room above cellar
min	682	8	167	15	5	385	61	25
max	5832	439	32943	115	32	5509	665	133
mean	4140	104	12437	60	20	3620	280	76

4. Automatic system for radon control in the house

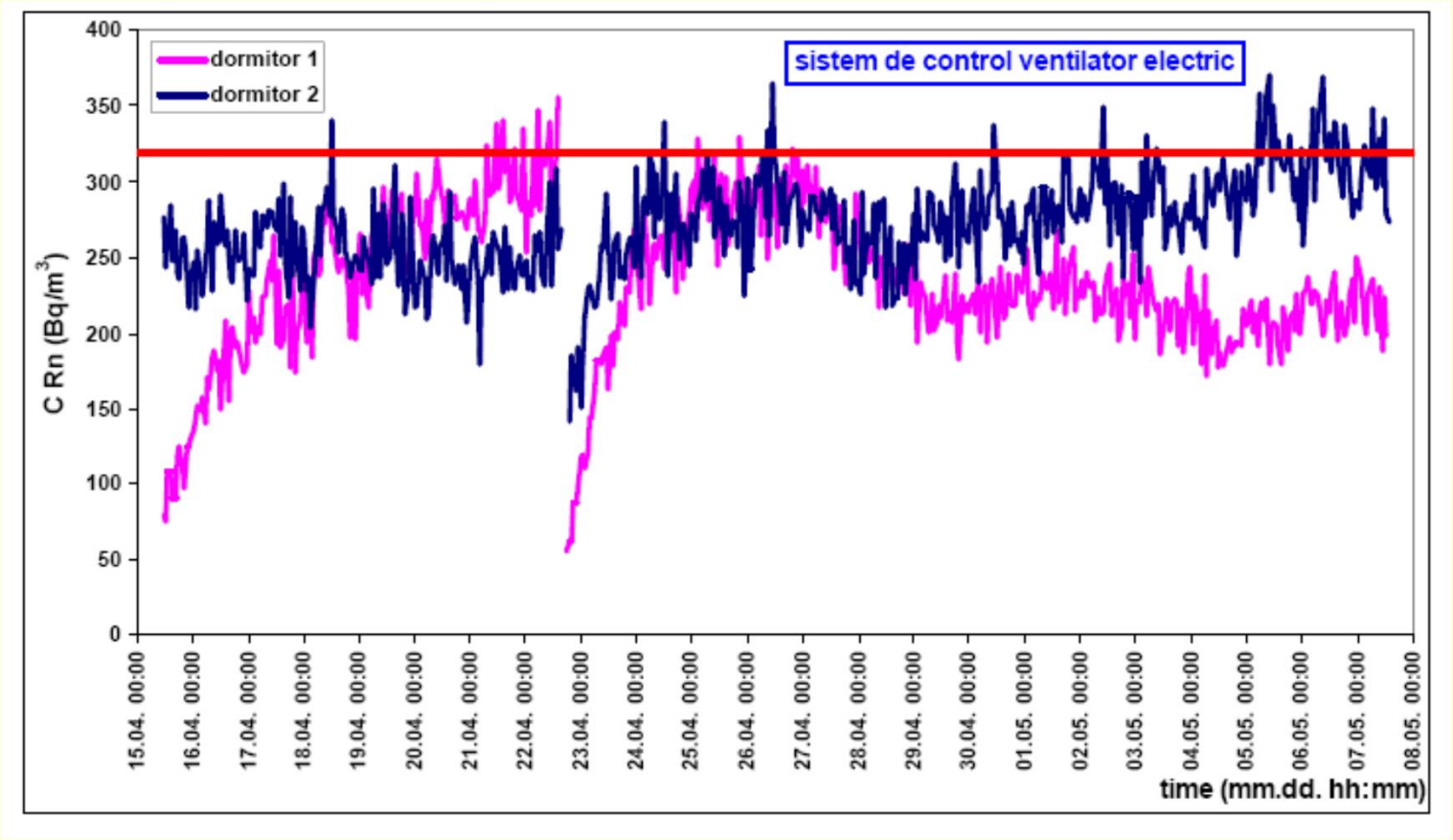




~ 200 Euro



Controlling radon system working

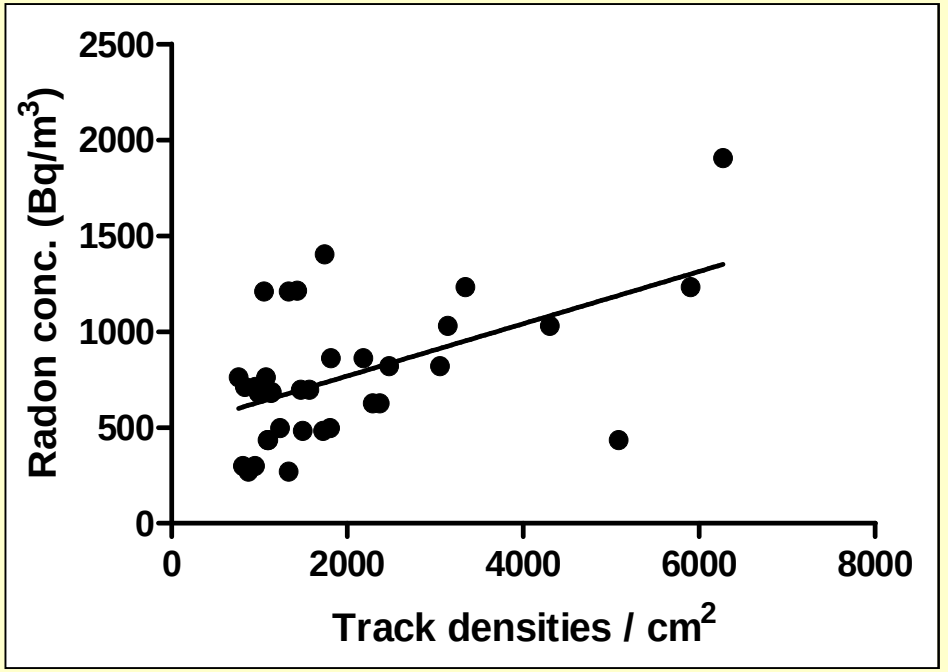


5. Retrospective Studies

Radon activity	Min. Value (Bq/m^3)	Max. Value (Bq/m^3)	Average Mean (Bq/m^3)	Geom. Mean (Bq/m^3)	St. Dev. (Bq/m^3)
Retrospective	172	1353	491	426	288
Contemporary	269	1404	763	683	344

$$C_{Rn} = \frac{245 * A_{Po}}{1 - e^{-\lambda_{210Pb} \cdot T}}$$

$$A_{210Po} = \frac{CR - B \times LR}{T \times K}$$



Thank you for Attention !!!