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Recent work with electronic radon detectors for continuous Radon-222 monitoring

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- c) Université Paris-Saclay, CEA, LIST, Laboratoire National Henri Becquerel (LNE-LNHB), F-91120 Palaiseau, France.

Motivation

Towards *continuous, metrologically assured, real-time* monitoring of ^{222}Rn in dwellings and workplaces.



01

Significant number of electronic radon monitors have emerged in the last two decades.



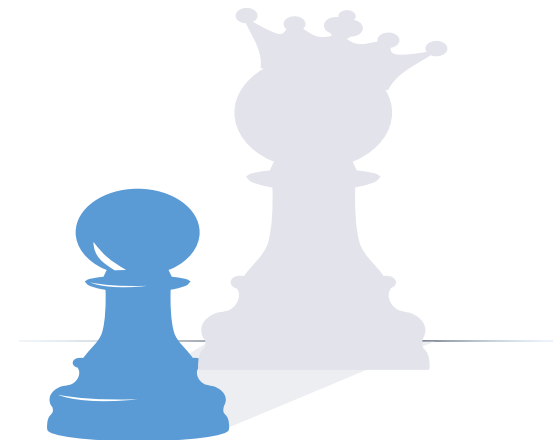
02

These detectors offer an interesting possibility for continuous radon monitoring in dwellings and workplaces



03

Can we perform long term (>1y), continuous measurements with these devices? How sensitive they are? How is it working for data collection, storage and analysis? Can we derive specific quantities with these devices (e.g. seasonal correction factors)? Can these be applied in radon mitigation activities, etc



Motivation

Table 2. Cross-interference signals for all cross-interference tests carried out at STUK and SUBG

Instrument	Tested at	s/n	Test dates	ICI (initial)	FCI (final)
AlphaE	STUK	000260	5–10 Jun 2019	6.5% ^a	9.3% ^a
			31 Jul–5 Aug 2019	8.9% ^a	12% ^a
	STUK	000542	11–17 Jun 2019	5.6% ^a	9.2% ^a
			31 Jul–5 Aug 2019	8.7% ^a	13% ^a
AlphaE	SUBG	000499	5–9 Dec 2019	5.7% ^a	8.6% ^a
			14–17 Oct 2019	4.5%	13.7%
AlphaGuard PQ2000 Pro (10-min diffusion mode)	STUK	EF1641	22–28 Oct 2019	11.5%	17.0%
			16–20 Sep 2019	10.0%	17.1%
			26–30 Sep 2019	12.7%	18.7%
			4–8 Nov 2019	15.5%	20.2%
AlphaGuard PQ2000 (10-min diffusion mode)	STUK	EF0408	22–27 Jan 2020	4.6–9.2%	6.0%
AlphaGuard 2000 RnTn Pro	IRSN	EF2283	18–22 May 2018		1.1%
			22–24 May 2018		0.6%
RadonEye +2	STUK	PE21812110009	20–23 August 2019	28%	42%
			PE21904100016	28 Nov–1 Dec 2019	27%
RadonEye +2	SUBG	PE21904100016	14–17 Oct 2019	32.6%	52.7%
			22–28 Oct 2019	38.7%	54.7%
			4–8 Nov 2019	18.7%	42.3%
Corentium Home	STUK	2403008304	20–24 Jun 2019		1.8%
			24–29 Jul 2019		2.5%
Airthings Wave	STUK	2900151289	28 Jun–2 Jul 2019		1.3%
			6–9 Aug 2019		2.3%
Airthings Wave Plus	STUK	2930	24–28 Jun 2019		2.7%
			24–29 Jul 2019		3.6%
Corentium Pro	STUK	2700007355	3–5 Sep 2018	0.2%	1.2%
			2700007357	3–5 Sep 2018	0.0%
TSR3 – Fast mode	SUBG	16014	16–20 Sep 2019	1.0%	7.7%
			26–30 Sep 2019	1.2%	12.3%
TSR3 – Slow mode	SUBG	16014	22–28 Oct 2019	2.7%	15.3%
TSR4M – Fast mode	SUBG	19015	22–28 Oct 2019	6.2%	125%
			16–20 Sep 2019	-	127%
			26–30 Sep 2019	-	186%
			4–8 Nov 2019	11.2%	114%
TSR4M – Slow mode	SUBG	19015	22–28 Oct 2019	15.9%	85.8%
			16–20 Sep 2019	-	69.5%
			26–30 Sep 2019	7.9%	115%
			4–8 Nov 2019	18.7%	76.4%
DoseMan Fast Mode	IRSN	DM357	18–22 May 2018	11%	36%
			22–24 May 2018	18%	39%
DoseMan Slow Mode	IRSN	DM357	18–22 May 2018	14%	41%
			22–24 May 2018	26%	48%



ORIGINAL RESEARCH

Testing of thoron cross-interference of continuous radon measuring instruments

Tuukka Turtiainen^{*1}, Krasimir Mitev², Rohafza Dehqanzada¹, Olli Holmgren¹ and Strahil Georgiev²

¹STUK—Radiation and Nuclear Safety Authority, Helsinki, Finland; ²Sofia University “St. Kliment Ohridski”, James Bourchier Blvd, Sofia, Bulgaria

We purchased 36 RadonEye+2 (RE) detectors



Range: from 7 to 9,435 Bq/m³,
Wifi Access (each 10 min),
internal storage (1 hour measurement)

Courtesy to Tuukka Turtiainen from STUK for the useful discussions and the information provided for the various detectors.

Contents

- *Laboratory tests of the response of detectors*
- *Data collection, handling and analysis*
- *First results of real-time monitoring of radon dynamics with these detectors*
- *Summary*

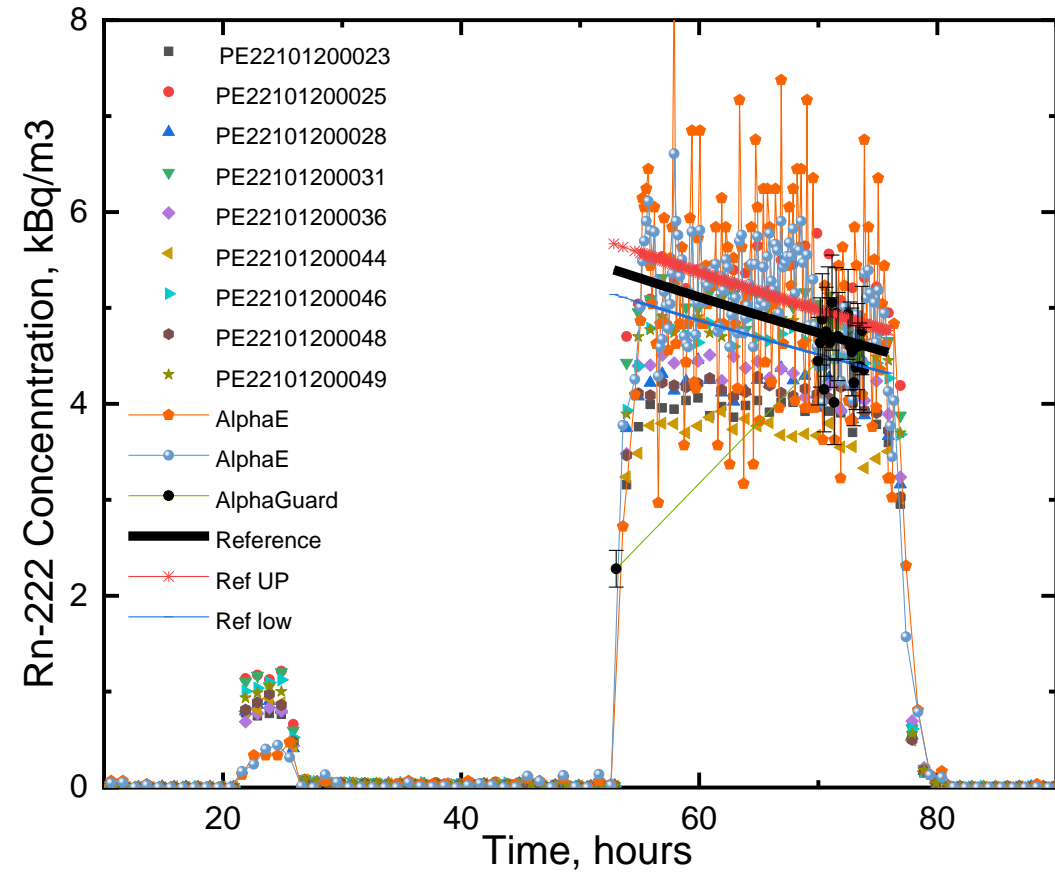
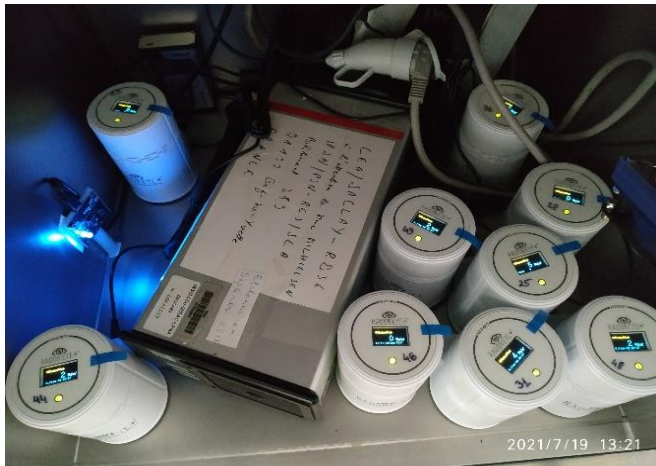
Laboratory tests of the response of RE detectors @ LNHB



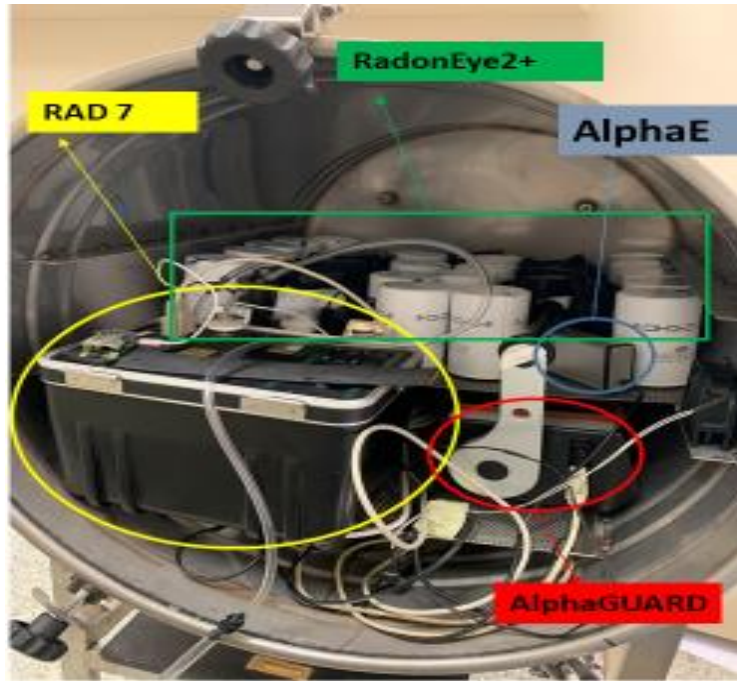
Experimental facility for the production of reference atmosphere of radioactive gases (Rn, Xe, Kr, and H isotopes)
 B. Sabot*, M. Rodrigues, S. Pierre
CEA, LIST, Laboratoire National Henri Becquerel (LNHB), 91191, Gif sur Yvette Cedex, France



AlphaE Sensitivity:
 3 cph at 100 Bq/m³



Laboratory tests of the response of RE detectors @ Sofia University



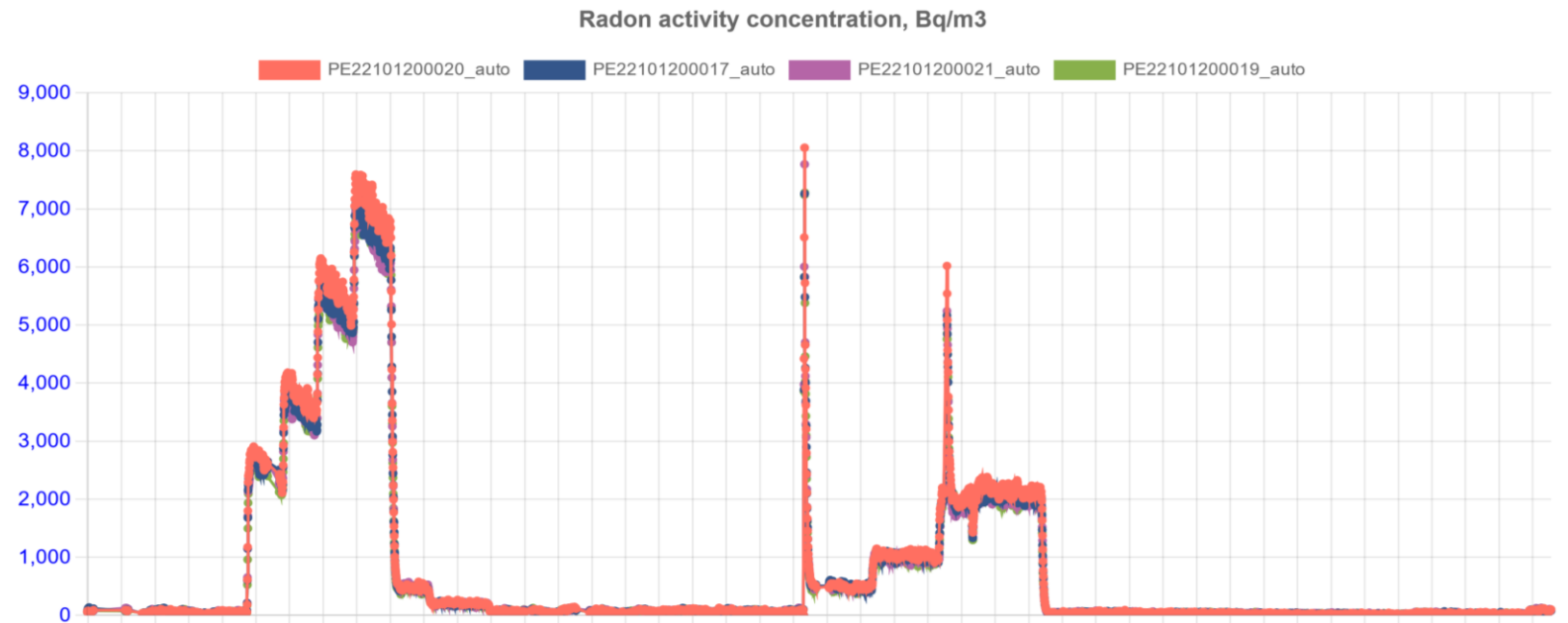
Laboratory facility to create reference radon + thoron atmosphere under dynamic exposure conditions

D. Pressyanov ^{a,*}, K. Mitev ^a, S. Georgiev ^a, I. Dimitrova ^a, J. Kolev ^b

^a Faculty of Physics, Sofia University "St. Kliment Ohridski", Sofia 1164, Bulgaria
^b Micon K Ltd., Varna 9000, Bulgaria

Upgraded:

- to host 40+ detectors
- Constant ²²²Rn concentrations in the lower A_v range



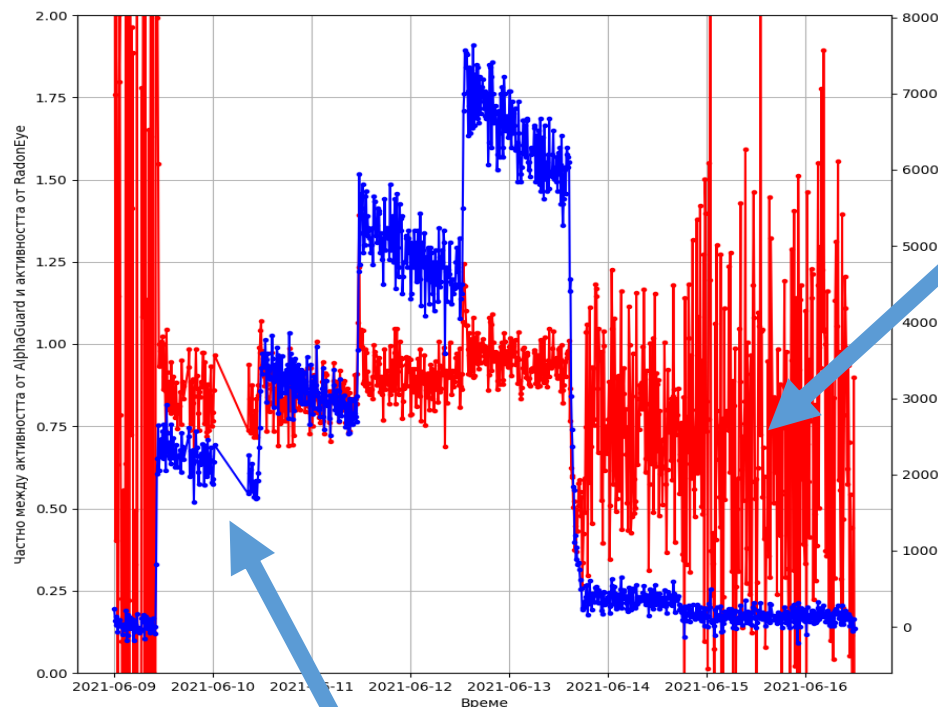
Results of the laboratory tests of the response of RadonEye+2 detectors

$$R = \frac{A_{V,ref}}{A_{V,RadonEye}}$$

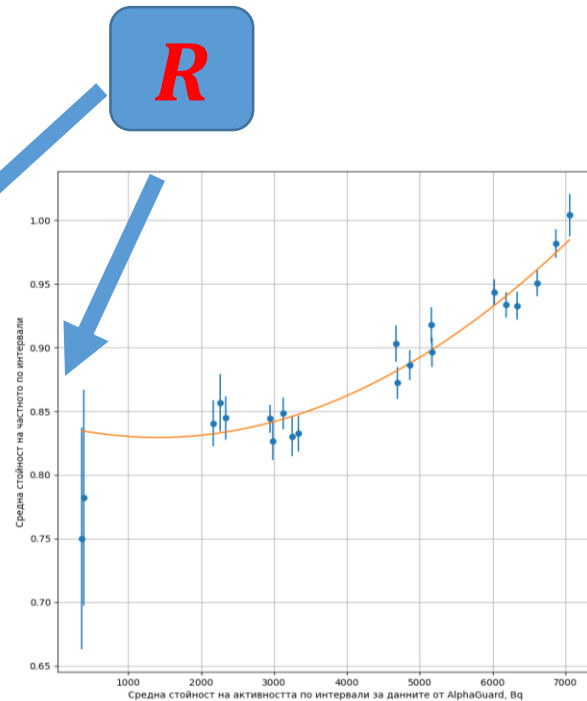


Radon Eye No	AG LNHB	
	R	σ_R
PE22101200023	1.210	0.066
PE22101200025	0.876	0.056
PE22101200028	1.155	0.070
PE22101200031	0.959	0.052
PE22101200036	1.138	0.063
PE22101200044	1.306	0.074
PE22101200046	1.025	0.054
PE22101200048	1.159	0.061
PE22101200049	0.976	0.055

$$\bar{R} = 1.09(14) \text{ @ } 4.6 \text{ kBq/m}^3$$



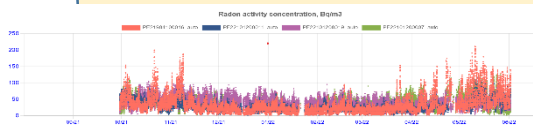
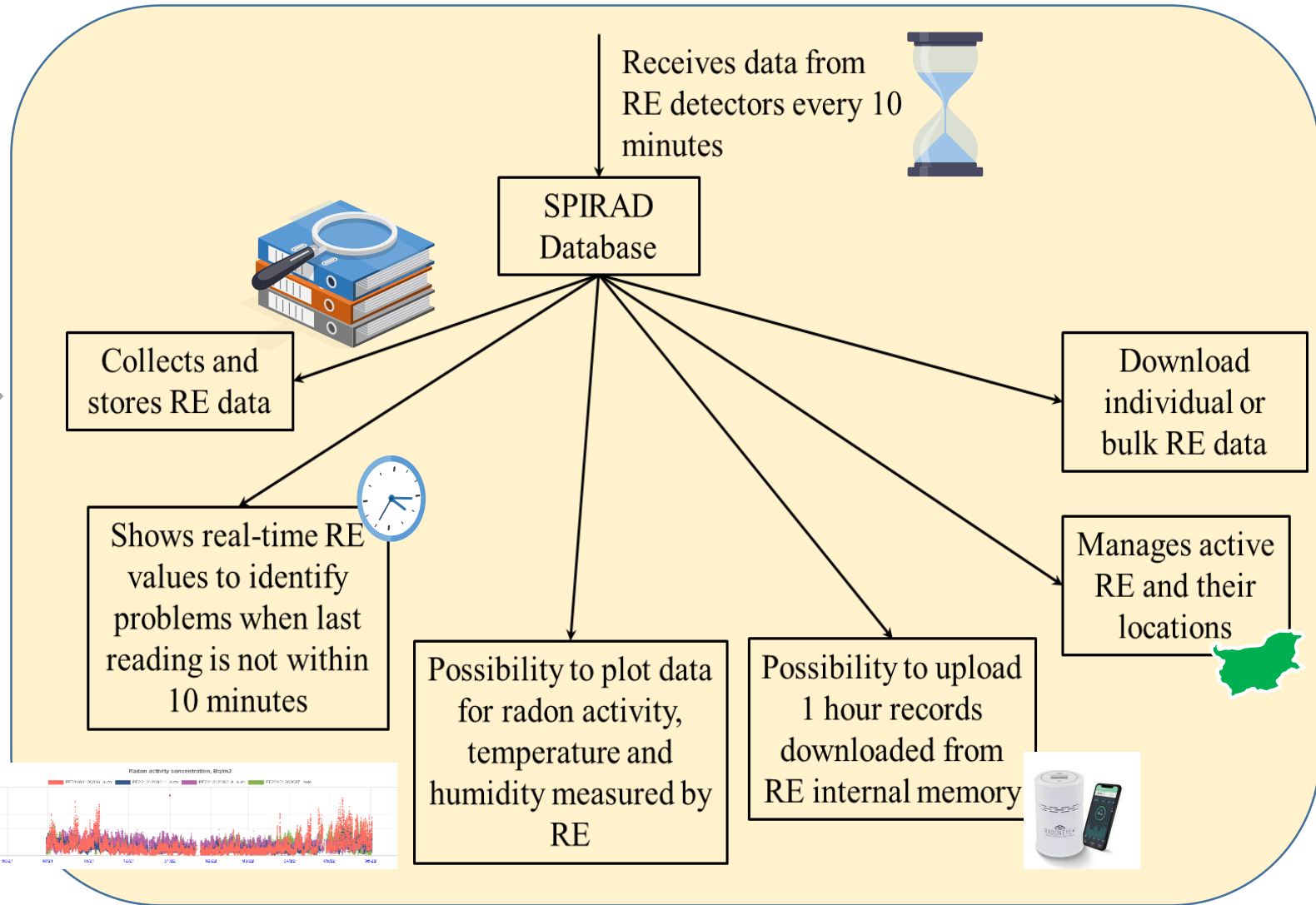
Radon activity concentration



Linear response in the range 0 – 3.5 kBq/m³

Slight non – linearity in the range 3.5 – 7 kBq/m³ (<15 %)

Data collection, handling and analysis – the SPIRAD database



Data collection, handling and analysis – the SPIRAD database

Select detectors

Write nicknames OR Add from list

Nickname1, Nickname2, ...

RE01 PE21904100016, RadonEye 2+
RE02 PE22101200007, RadonEye 2+
RE03 PE22101200011, RadonEye 2+
RE04 PE22101200017, RadonEye 2+
RE05 PE22101200019, RadonEye 2+
RE06 PE22101200020, RadonEye 2+

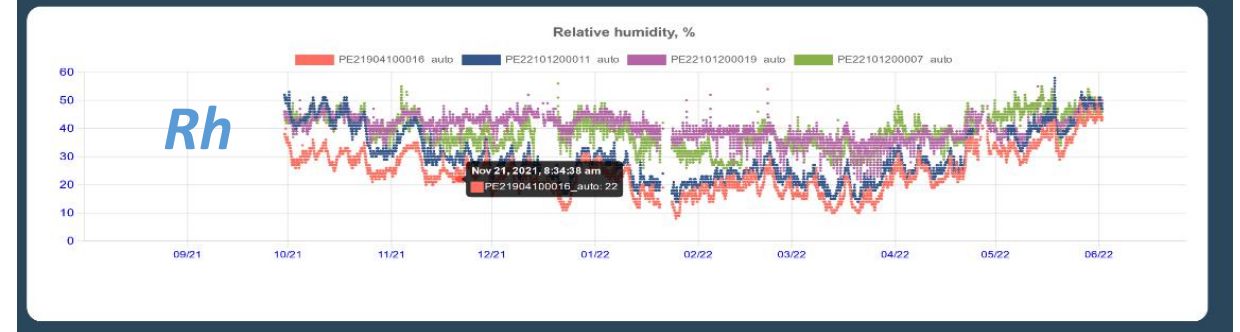
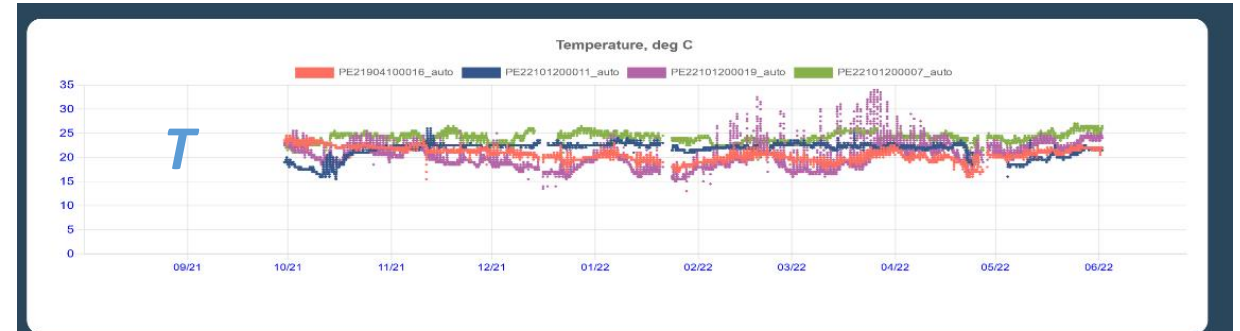
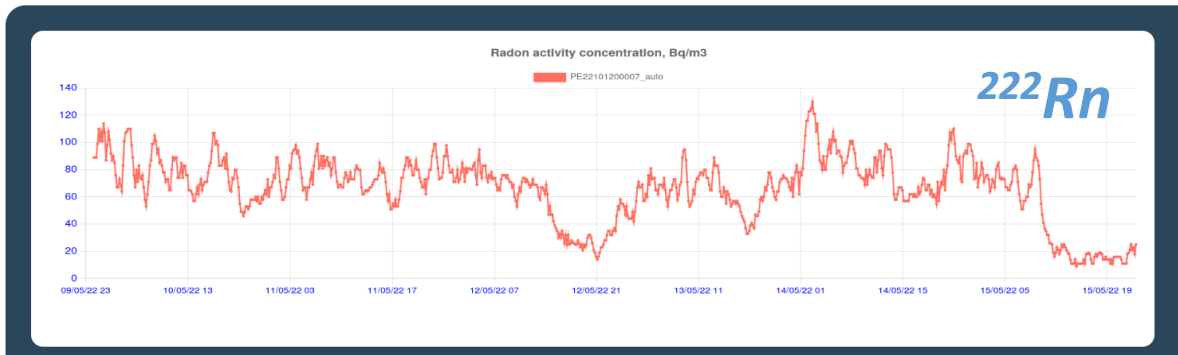
Input Type (For RadonEye) auto

Start Date (Optional) 05 / 10 / 2022 UTC time

End Date (Optional) 05 / 15 / 2022 UTC time

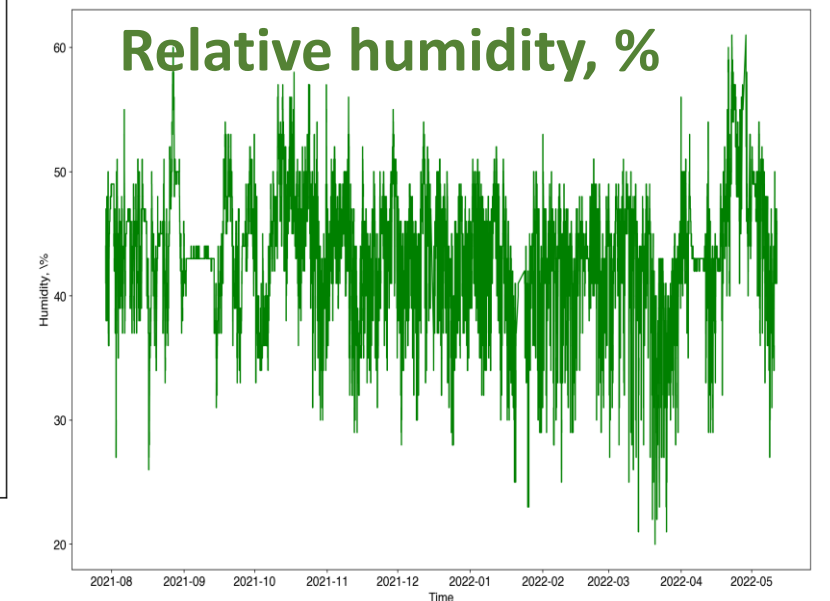
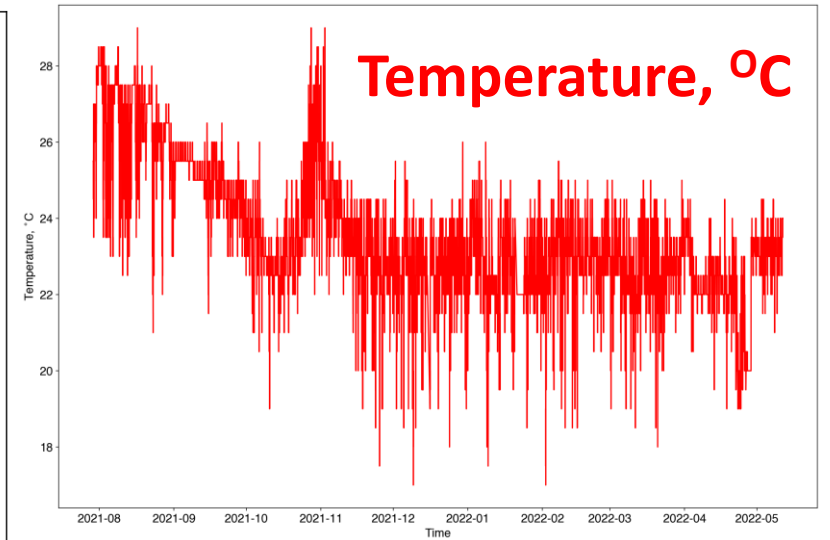
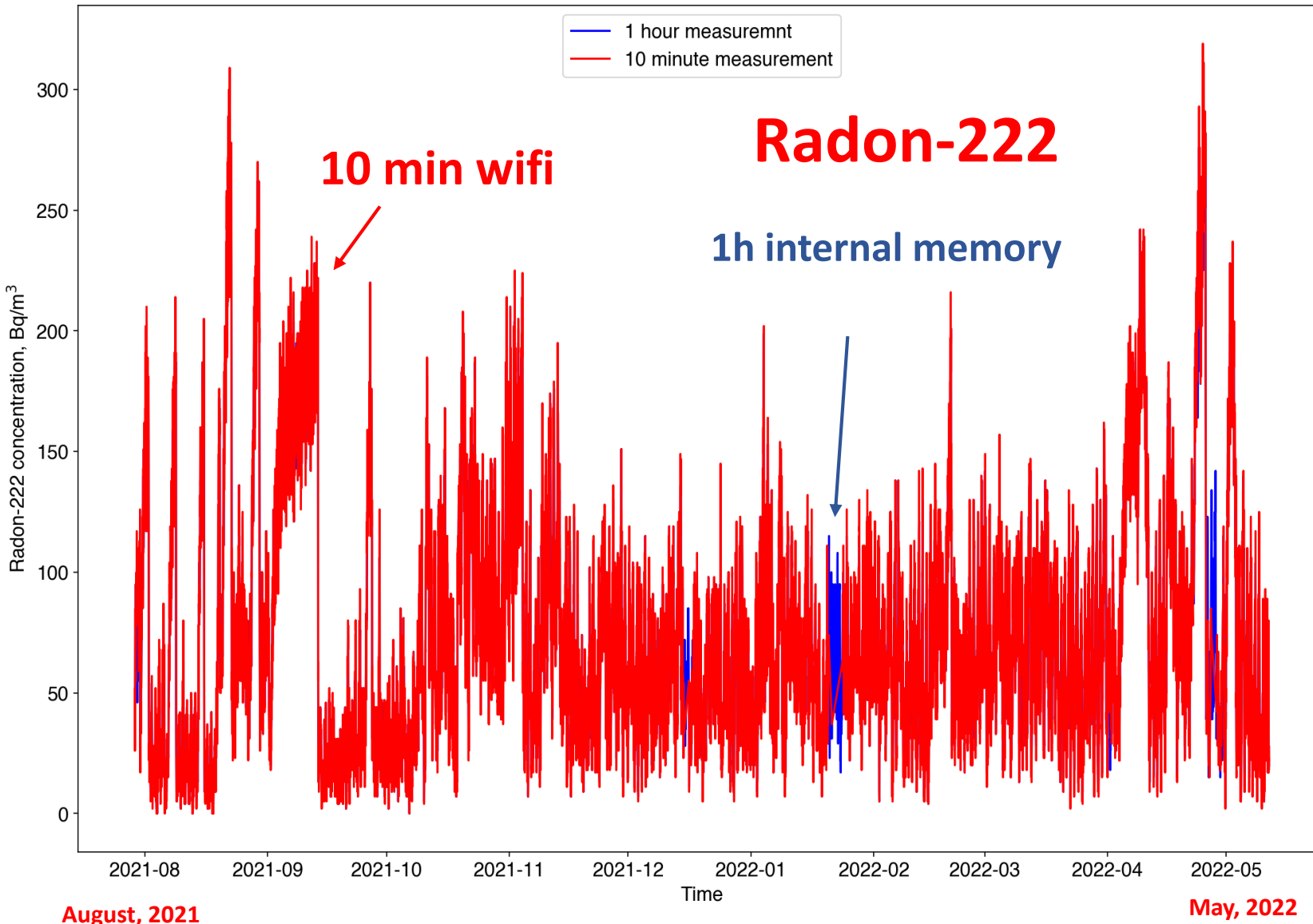
Show charts

Select



The SPIRAD database allows to output measurement data in formats convenient for application of machine learning algorithms, time series analysis, etc.

Results: Example from a measurement in a house (10 months)



Results: Uptime & Active (>90% of the total time)



RadonEye +2 Wifi broadcasting (10 min reports, uptime >91% of the total time)

Det	date placed at location	started broadcasting	uptime	downtime	Uptime, %
RE07	2021-07-28 10:30:00	2021-07-28 11:08:03	263 days 20:21:37	23 days 10:37:39	91.8
RE11	2021-07-29 11:55:00	2021-07-29 11:55:28	264 days 23:17:55	21 days 06:54:43	92.6
RE16	2021-06-10 08:30:00	2021-06-10 10:07:45	314 days 23:03:15	19 days 07:30:10	94.2
RE19	2021-07-28 13:00:00	2021-07-28 13:29:37	272 days 22:46:30	14 days 05:47:23	95.0
RE33	2021-07-29 10:00:00	2021-07-29 11:28:06	272 days 01:00:43	14 days 05:38:42	95.0
RE34	2022-02-18 07:00:00	2022-02-18 09:30:13	75 days 23:44:43	6 days 08:53:51	92.3



RadonEye +2 internal memory (1 hour record, uptime >96% of the total time)

Det	date placed at location	started broadcasting	uptime	downtime	Uptime, %
RE07	2021-07-28 10:30:00	2021-07-28 11:08:03	270 days 03:41:22	10 days 20:07:50	96.14
RE11	2021-07-29 11:55:00	2021-07-29 11:55:28	285 days 13:24:31	0 days 14:57:11	99.78
RE33	2021-07-29 10:00:00	2021-07-29 11:28:06	285 days 16:26:00	0 days 10:53:24	99.84

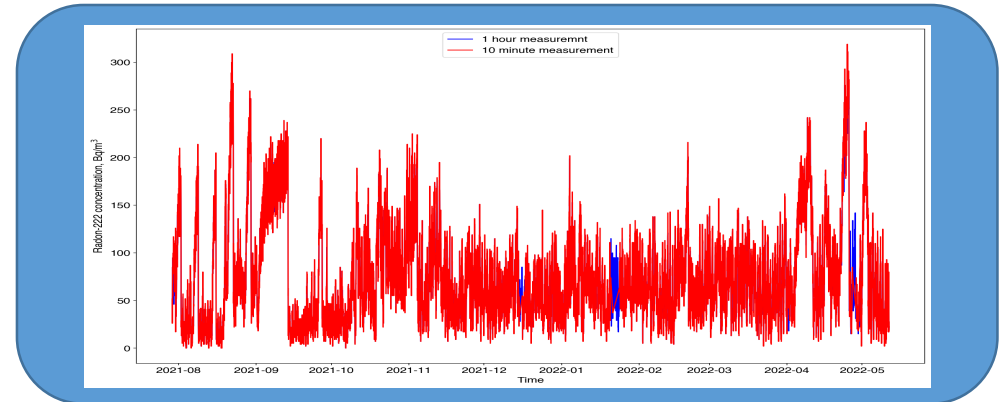
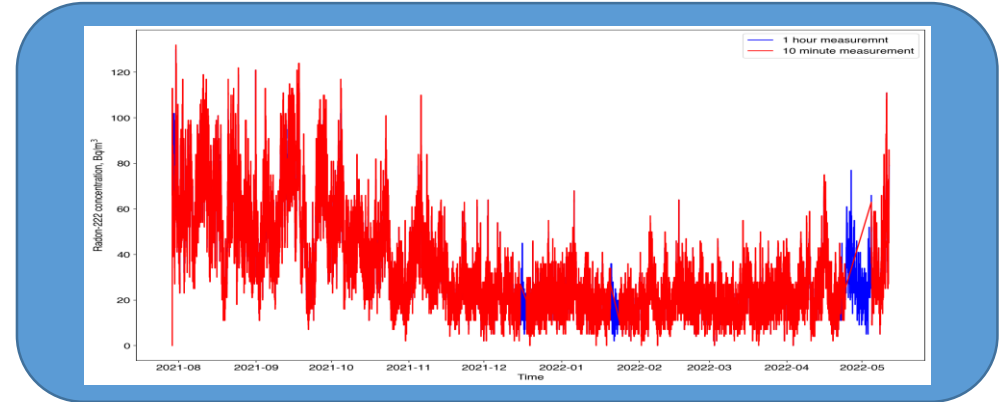
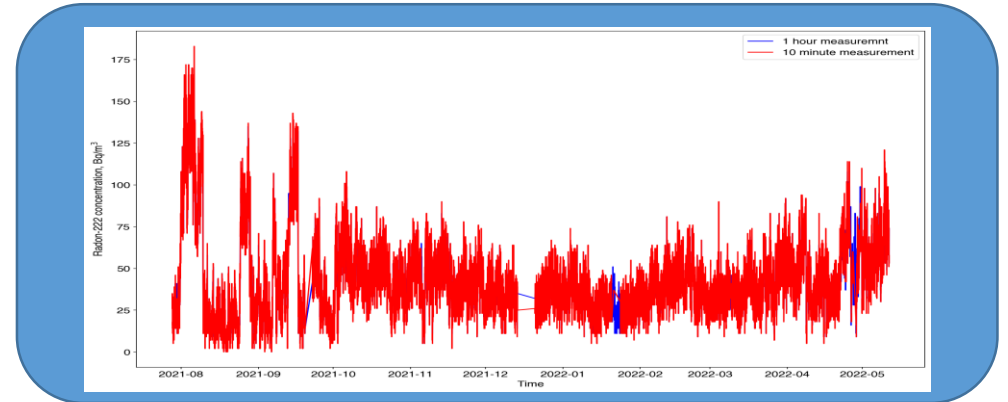
Results: ^{222}Rn statistics (examples). Excellent agreement



RE07	Wifi	Internal storage
	10 min measurements	1 h measurements
MEAN	42.5	42.6
STDEV	22.9	22.9
MEDIAN	39	39
MAD	12	12

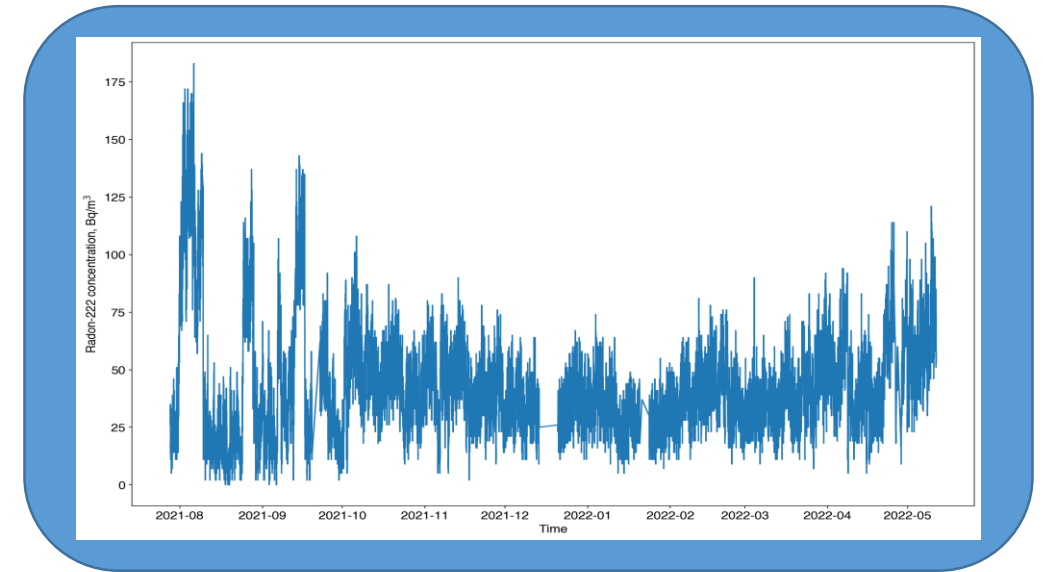
RE11	Wifi	Internal storage
	10 min measurements	1 h measurements
MEAN	33.8	33.3
STDEV	21.6	21.4
MEDIAN	27	27
MAD	11	11

RE33	Wifi	Internal storage
	10 min measurements	1 measurements
MEAN	73.7	74.2
STDEV	49	49.5
MEDIAN	63	63
MAD	28	28

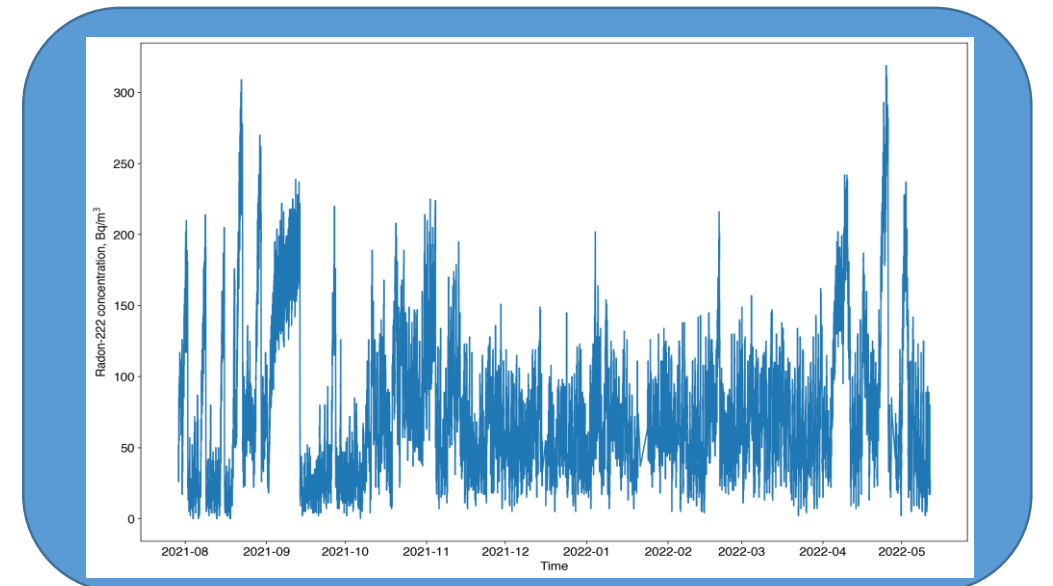


Results: Studies of seasonal ^{222}Rn dynamics (examples)

	RE07 (9 months measurements)			
	Autumn	Winter	All	Autumn/All
MEAN	41.8	35.1	42.5	0.984
STDEV	15.3	11	22.9	
STDEV MEAN	0.1	0.1	0.1	
MEDIAN	41	35	39	1.051
MAD	10	7	12	



	RE33(10 months measurements)			
	Autumn	Winter	All	Autumn/All
MEAN	68.4	65.7	73.7	0.928
STDEV	40.3	29.1	49	
STDEV MEAN	0.4	0.3	0.2	
MEDIAN	59	63	63	0.937
MAD	26	20	28	



Summary



01

The RadonEye+2 are good instruments for continuous radon monitoring
Calibration factor within 15% to the reference, linear below 3.5 Bq/m^3 , slight non-linearity for radon concentrations in the interval $3.5\text{-}7 \text{ kBq/m}^3$

02

The online database is an important tool to collect, store and visualize radon data
Monitors and assures reliable operation and data storage. Creates warnings when the connection with the detectors is lost. Enables real time radon monitoring at many places

03

Excellent data collection efficiency
> 91 % uptime online, >96% uptime with internal storage. Convenient interface for data analysis (machine learning, AI, time series, etc.)

04

Provides reliable data for indoor radon dynamics, which is useful for various purposes
E.g. Evaluation of early average radon concentration, seasonal correction factors, radon correlation with environmental factors, etc..



ФОНД
НАУЧНИ
ИЗСЛЕДВАНИЯ

МИНИСТЕРСТВО НА ОБРАЗОВАНИЕТО И НАУКАТА



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contract KP-06-H48/3 from 26.11.2020.

Thank you for your attention.