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Long-term study of radon concentration dynamics in a four-storey building

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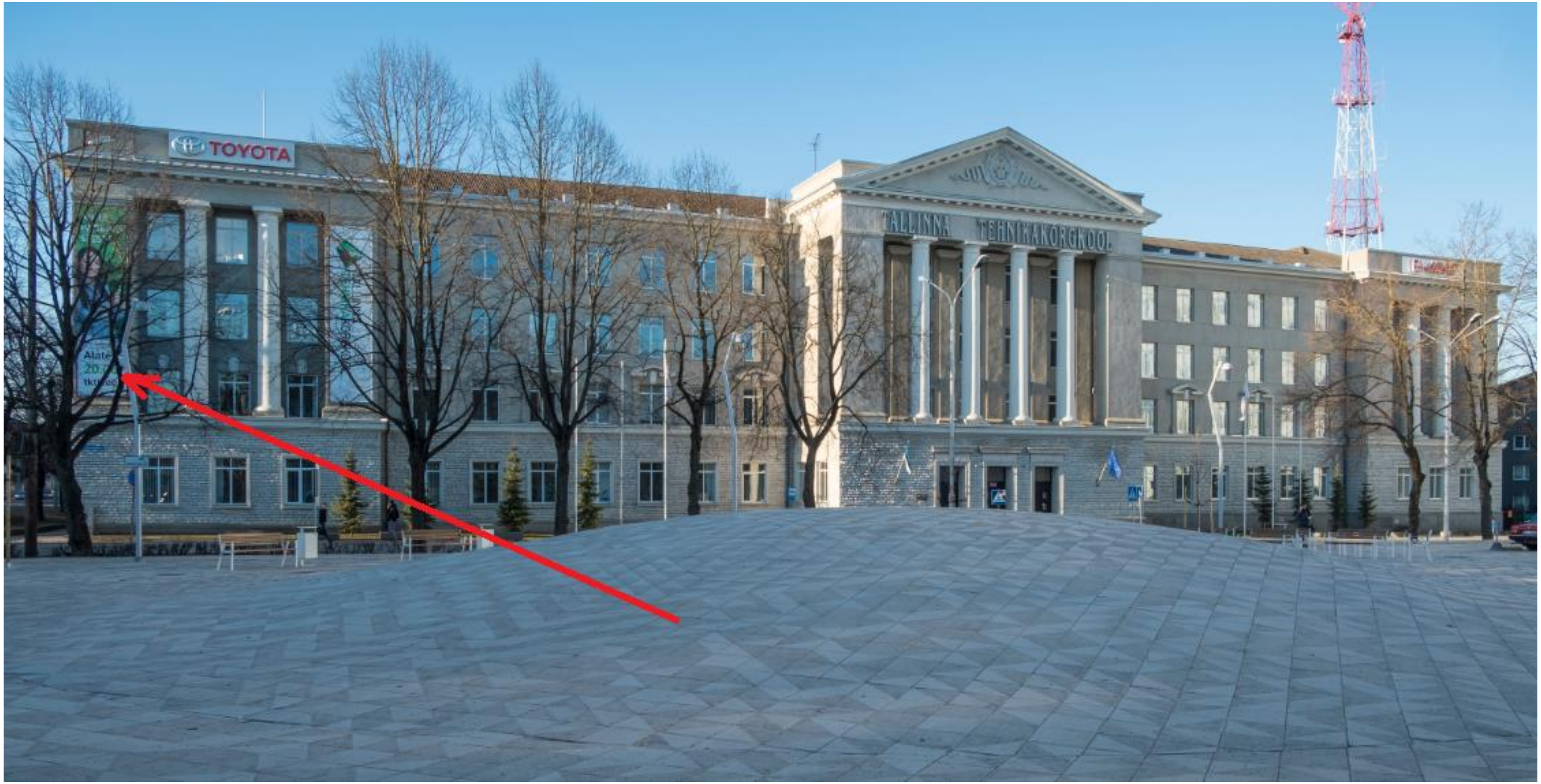
Introduction

- The measured radon activity concentrations in Estonian soil gas varies on average between 23 and 75 kBq/m^3. The highest measured values for radon activity concentrations in soil gas have been more than 500 kBq/m^3.
- The main sources of radon in the soil air are the uranium-containing graptolitic argillite, phosphorite, Devonian bedrock and tectonic cracks in the ground.
- Estonia is among the five highest radon risk countries in Europe, with the Czech Republic, Luxembourg, Sweden and Finland, in terms of average levels of its radon concentrations in indoor air.
- According to directive EURATOM 58/2013 it is needed to carry out radon measurements in workplaces that are located on the ground floor or basement level. But according to construction peculiarities, these measurements must also be carried out in the rooms on the upper floors.
- Longterm (twelve month) radon active measurements were carried out in all rooms one above the other.

Main Building



Description of the building

Location: Estonia, Tallinn city;

Built: in 1952;

Building materials - natural building stones as limestone, gypsum and reinforced concrete structures;

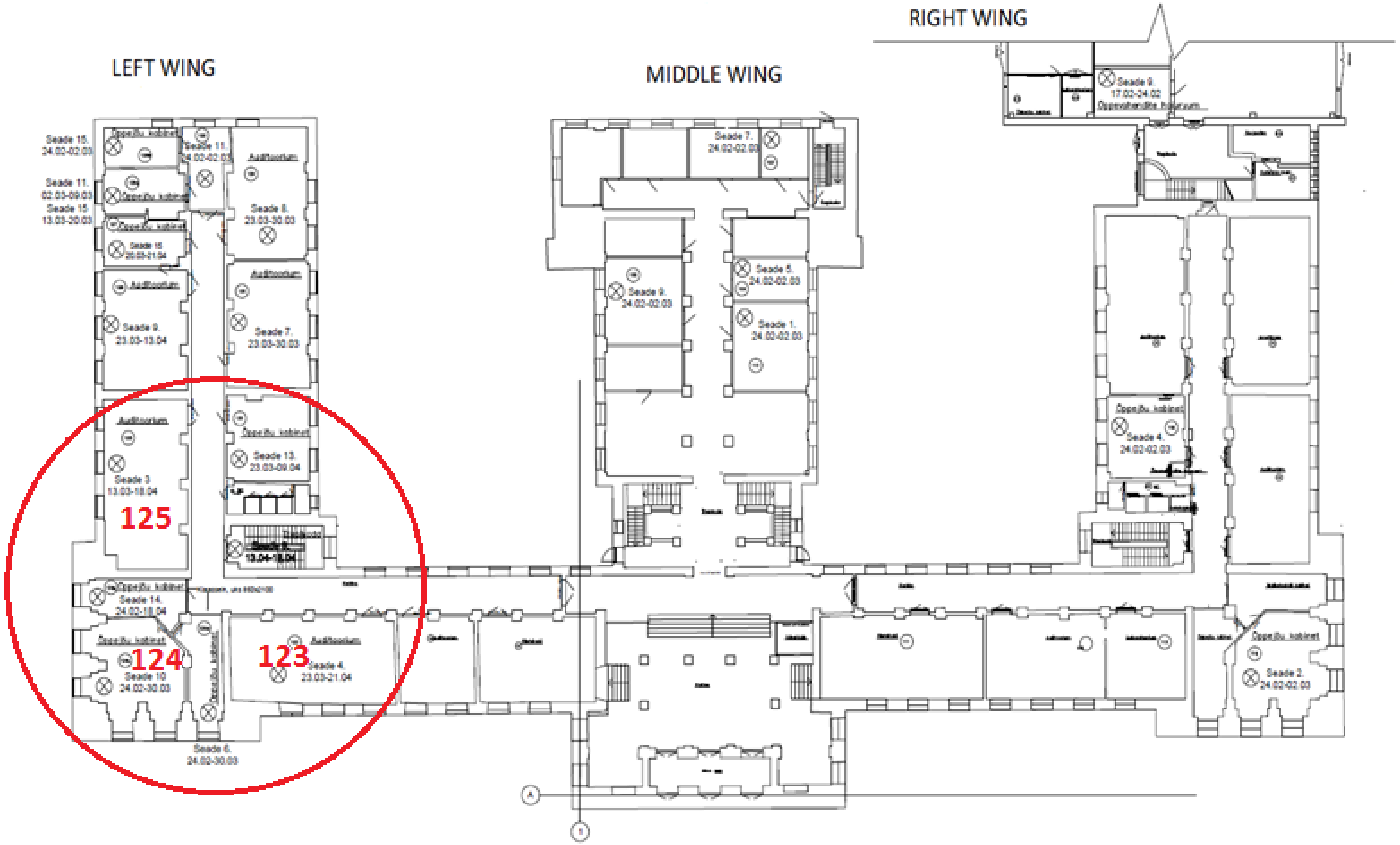
Building has six floors including zero floor: one underground floor, four aboveground floors and also an attic, which is not in use;

From the plan view the building is E-shaped and divided into left, middle and right wings. There is no basement under the left wing;

The building has a mechanical supply and exhaust ventilation system. The ventilation units are located on the attic floor. The ventilation system of the building is in working mode mostly on working days from 06.00 to 18.00.

Description of the building

First Floor Building Plan

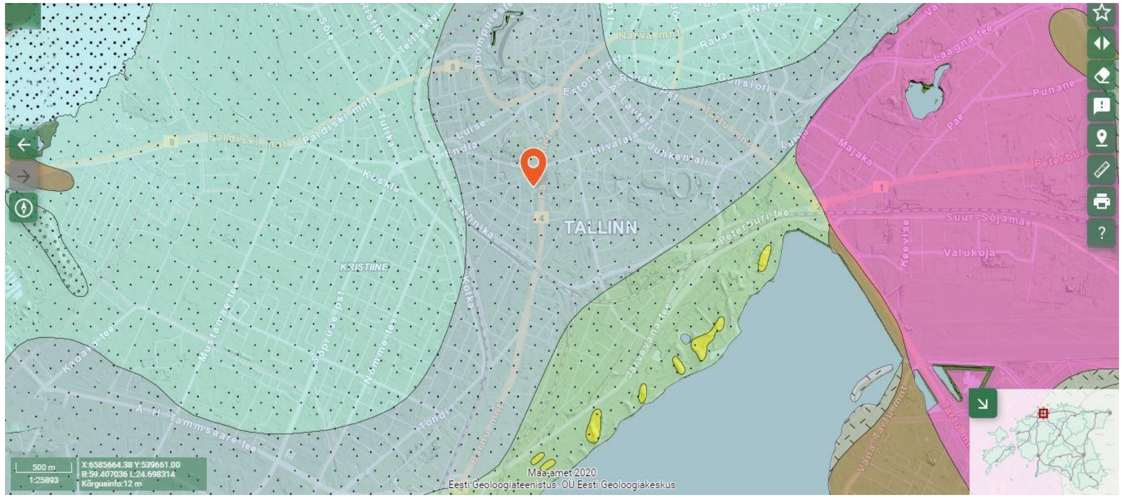


Possible radon leakage and pathways

According to the building's ventilation plans, vertical ventilation shafts pass through the floors of the building. Along these shafts, radon can move from the lower floors to the upper floors and enter the rooms through the ventilation ducts. Radon-transmitting cavities can be located in the pillars passing through the building, which are built as hollows inside. As it is relatively old building, old technical system shafts and/or pipelines, that are no longer used and have not been closed or removed, may pass through the building.

Location and Geological Conditions

Surface coating map shows different sediments of Littorina Sea period. Therefore building is located on marine sediments (blue color on the map), which contain gravel, sand, silt, sandy clay, aleurite, loam, bay muds. In addition, these sediments contain variable quantity of graptolitic argillite and phosphorite crushed pieces, which are the main source of radon; radon air can migrate into the building from the surface soils.

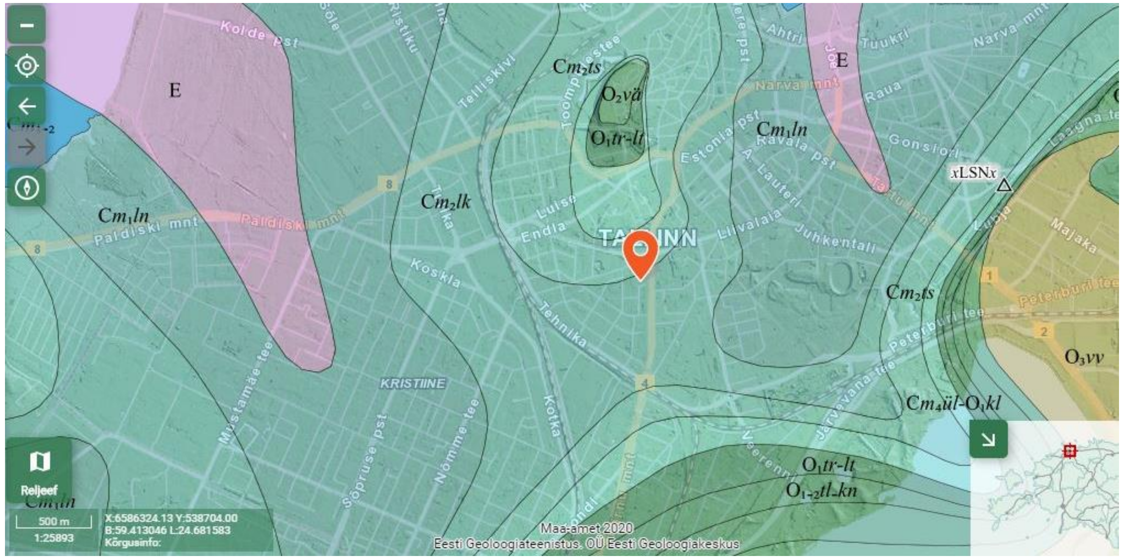


Location and Geological Conditions

Geological Bedrock map shows that there are many Cambrian rock layers and rock types for different geological ages at the building area, which are lying under the surface soils. Two nearest formations are *Cm*$_2$*lk* and *Cm*$_2$*ts*:

Cm$_2$*lk* – basic formation under the building, Early Cambrian formation (local name Lükati formation) thickness is 7–16 m, it contains blue clays, where aleurite clay content is dominating ~60–70%, and it also contains fine-grained quarz sandstone layers.

Cm$_2$*ts* - Cambrian Series formation (local name Tiskre formation) thickness is 16–21 m and thickness is constant, is represented by fine-grained, weak- to medium-cemented light grey quarz sandstone of the Early Cambrian or coarse-grained quarz aleurite. Sandstone contain glauconite clay with aleurite layers.



Location and Geological Conditions

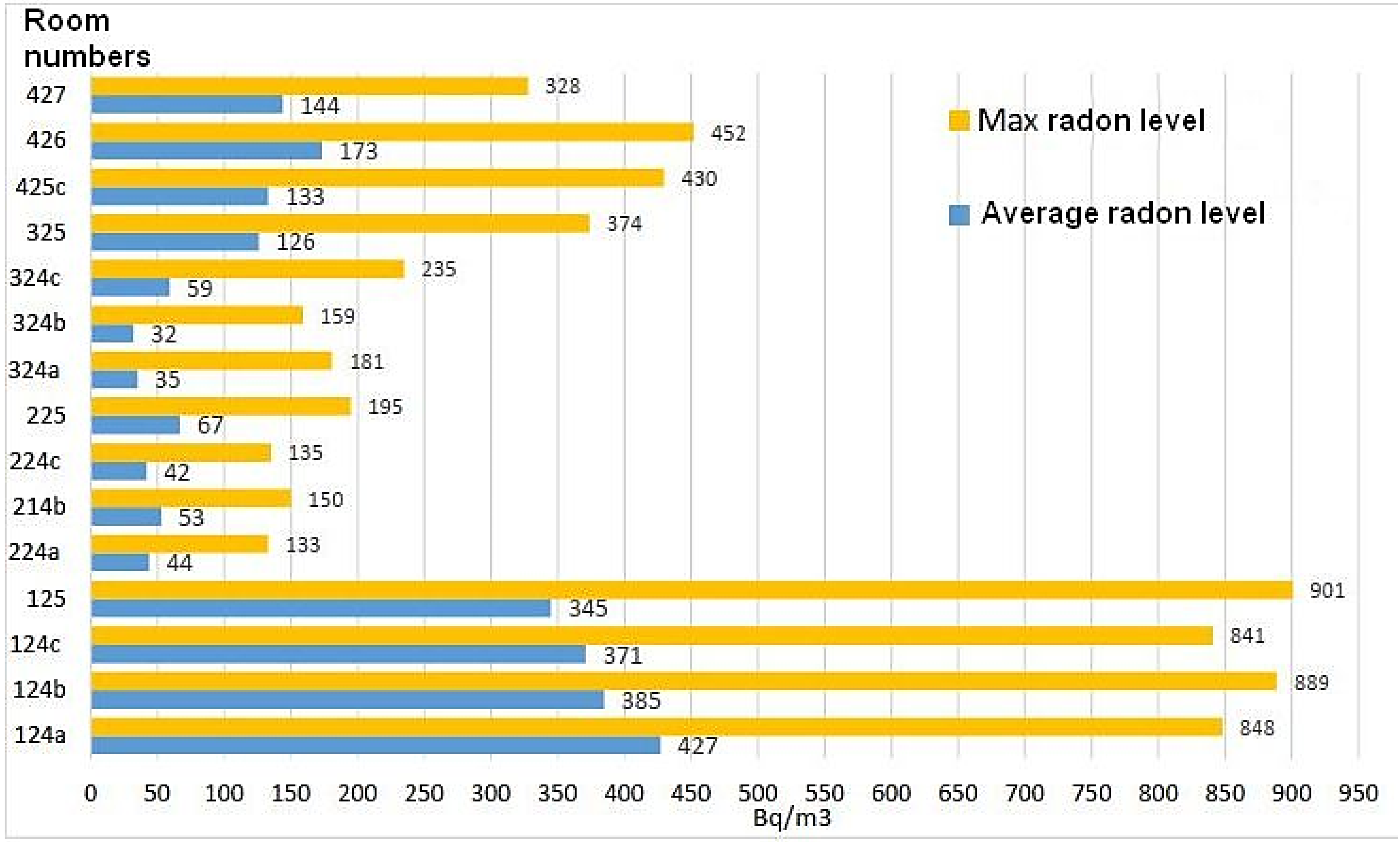
At the 300 m area radius near the building can be found also such rocks formations as *Cm_4ül-O_1kl* and *O_1tr-lt* with different composition mix:
Cm_4ül-O_1kl - Lower Ordovician series (local name Ülgase and Kallavere formation), thickness is 4-12 m. Kallavere formation belongs to period and it contains a lot of phosphorite.
O_1tr-lt – Ordovician Formations (local names are Türisalu and Leetse). Türisalu thickness is only 0–2 m, but it consist of graptolitic argillite. Leetse formation (*O_1lt*) has small thickness (0,5-1,5 m), it contais fine particles of grey and greenish glauconitic sandstone.

As a result, it can be concluded that the building is located on high radon risk area; because there are formations containing phosphorite, graptolite-argillite

Methodology

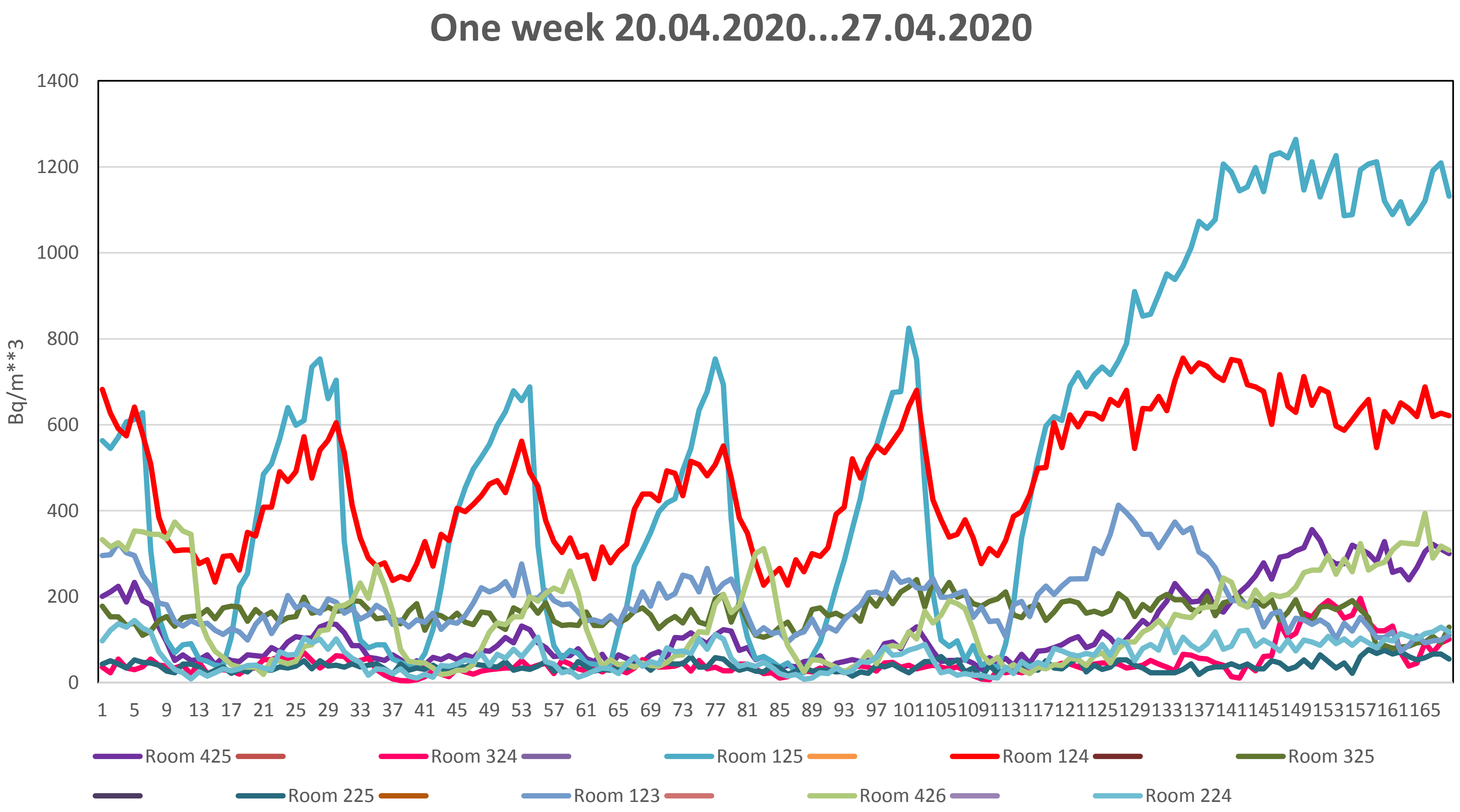
- For indoor radon measurements RadonEye Plus2 detector devices were used.
- RadonEye Plus2 total readings in the radon chamber during 20 days comparison differed by less than 3.5% from AlphaGuard total readings.
- In spring 2020, one-week measurements of radon activity concentrations were carried out on all floors of the building at homogeneous zones.
- The results of this study showed an increase in radon mean activity concentration values in the left-wing rooms of the building.

Results of one week measurement



Measurements

Typical one week pattern



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Results of one year monitoring

	Fourth floor						Third floor						Second floor						First floor								
Room	425			426			324			325			224			225			124			125			123		
	Av.	Med.	Max	Av.	Med.	Max	Av.	Med.	Max	Av.	Med.	Max	Av.	Med.	Max	Av.	Med.	Max	Av.	Med.	Max	Av.	Med.	Max	Av.	Med.	Max
Mar.	134	112	430	173	161	452	59	46	235	124	122	205	69	68	207	108	108	394	508	531	814	366	364	956	162	140	430
Apr.	106	72	356	108	46	440	46	34	213	70	40	314	68	57	227	47	37	187	510	499	1184	349	312	1264	147	136	430
May	9	7	44	9	5	47	11	7	72	11	7	72	23	8	176	9	5	61	130	71	613	30	9	333	40	37	168
Jun.	15	9	111	22	8	129	22	11	104	16	8	108	43	13	225	20	10	122	173	69	1029	45	16	293	45	37	225
Jul.	16	10	93	13	8	79	24	11	119	11	7	72	47	11	309	21	8	191	199	77	1198	85	14	624	94	70	662
Aug.	16	5	288	23	8	371	13	7	113	11	7	72	19	5	149	8	5	75	109	33	947	33	5	797	31	25	154
Sept.	26	9	270	43	10	326	17	11	148	24	9	264	27	11	191	14	8	139	163	73	804	51	11	587	46	39	207
Oct.	56	14	318	74	15	411	27	11	203	11	7	72	34	11	180	17	8	154	207	102	941	142	28	821	45	25	241
Nov.	78	23	346	136	86	417	42	18	207	70	21	320	41	21	191	25	11	221	264	170	954	192	70	827	87	66	337
Dec.	203	242	395	212	263	438	100	85	303	11	7	72	74	82	162	50	55	134	406	452	661	496	575	875	169	138	447
Jan.	113	66	395	153	110	503	40	16	300	11	7	72	36	21	174	28	17	162	303	266	765	299	229	1007	169	110	536
Feb.	120	72	399	117	36	498	56	20	278	119	55	454	46	26	244	42	17	246	356	322	839	263	148	857	84	44	603

Conclusions

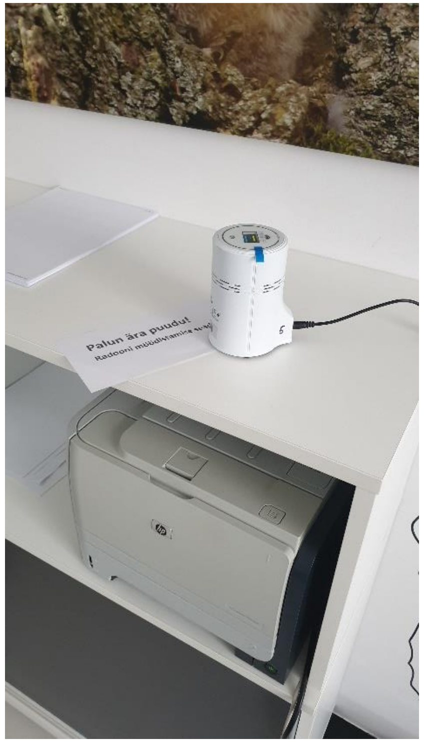
It is very important to conclude, that it is not sufficient to held measurements only at the basements or at the 1st floors. The results of the measurement revealed that radon can easily migrate to the upper floors of the buildings as it passes intermediate floors. In addition, it was found that radon is distributed at the building very unevenly and therefore all working space of the whole building should be measured.

Ventilation is good, but quite expensive solution to radon problems.

Literature

1. Pilisner, Sander (2020) *Radon Safety Monitoring in the Main Building of Tallinn University of Applied Sciences*.
2. The Geological Survey of Estonia, *Estonian geological map headnote, Tallinn, 2011, p. 111.*
3. *COUNCIL DIRECTIVE 2013/59/EURATOM of 5 December 2013.*
4. Šommet, J. Koch, R. Paap, L.: *Impact of Geological Conditions and Constructional Features on Indoor Radon. Utrecht 2020*.

Thank you for your patience!


Palun ära puudu!