INDOOR RADON CONCENTRATIONS IN SELECTED BUILDINGS OF GEORGIA

*Kapanadze N., *Melikadze G., *Tchankvetadze A., *Todadze M., *Jimsheladze T., *Gogichaishvili Sh., **Chelidze L., *Chikviladze E., ***Vaupotič J.

*Mikheil Nodia Institute of Geophysics of Ivane Javakhishvili Tbilisi State University, Tbilisi, Georgia
**Elevter Andronikashvili Institute of Physics of Ivane Javakhishvili Tbilisi State University, Tbilisi, Georgia
***Jožef Stefan Institute, Ljubljana, Slovenia
ninokapanadze@gmail.com

Abstract. *Within the project "Radon mapping and radon risk assessment in Georgia", funded by the Shota Rustaveli National Science Foundation of Georgia* in 2019–*2022 (*SRNSFG FN-19-22022)*, systematic radon (^{222}Rn, Rn) surveys in indoor air, soil gas, and waters were carried out in Georgia. The indoor radon study included 702 locations in 11 administrative regions of Georgia. Altogether, 1338 rooms in 107 schools, 540 kindergartens, 6 city halls, and 57 homes were examined for radon all year round by exposing solid-state nuclear track detectors RSFV from Radosys Ltd. Rn concentrations ranged from 2 to 1226 Bq m^{-3}, with an annual arithmetic mean value of 84 Bq m^{-3} for all the regions. The annual effective doses ranged from 0.2 to 3.8 mSv with an arithmetic mean value of 1.2 mSv a^{-1}.*

***Keywords:** radon, indoor air, solid state nuclear track detector, effective dose, Georgia*

Introduction

Noble gas radon (^{222}Rn, Rn) originates in the natural radioactive decay chain of uranium (^{238}U) in the earth's crust. From its origin, radon migrates to the surface by diffusion and advection, affected by a number of geophysical and hydrometeorological parameters. Rn α-decay is followed by radioactive transformations, in which its progeny (RnP: ^{218}Po, ^{214}Pb, ^{214}Bi, ^{214}Po) are formed. Rn and RnP are present ubiquitously in the air, and during breathing, Rn is exhaled while RnP are partly deposited on the walls of the respiratory tract. The energy released by their radioactive transformations is absorbed in the nearby tissue, damages it and eventually increases the risk of lung cancer.

The primary site of Rn exposure is indoors, where a person spends up to 80 % of the time. Geology, climate, quality of building construction and living habits mainly affect the distribution of Rn indoors. It has been estimated that a member of the general public receives from Rn and RnP about half of the annual effective dose (1.2 mSv), compared with a total of 2.4 mSv from all sources of natural radioactivity [1].

The territory of Georgia belongs to the Alpine tectonic zone. They encompass different geological formations containing significant concentrations of radioactive elements. The most significant amount of Rn is released to the soil gas from rocks of the Palaeozoic and Jurassic ages, where the content of radioactive elements varies greatly. The country is abundant with tectonic faults where radon-rich natural mineral water sources are present, situated in several highly populated parts of Georgia. Several radon studies covered only small parts of the country and were episodic. In the frame of the project "Assessment of radon-hazard potential, residential exposure, lung cancer and COPD in West Georgia", the outflow of gas associated with tectonic faults was studied and confirmed the correlation between Rn exhalation and prevalence of lung cancer [2–3]. Pagava et al. (2008) [4] reported concentrations of Rn in residential buildings (30–380 Bq m^{-3}). Within the project "Complex Research of Earthquake's Prediction Possibilities, Seismicity and Climate Change Correlations" (BlackSeaHazNet), the range of indoor radon 12.9–1110 Bq m^{-3}, and thoron 6.3–681 Bq m^{-3}, concentrations were found [5].

In the project "Radon mapping and radon risk assessment in Georgia", part of the research was intended for the first systematic indoor radon survey within 11 administrative regions. This paper reports a summary statistic of indoor radon concentrations and the estimated annual effective doses, separately for schools, kindergartens, and homes for each region, and the cumulative frequency of indoor radon concentrations for the whole country.

Materials and Methods

Radon concentrations were measured by long-term exposure of Radosys RSFV solid-state nuclear state detectors (track-etch detectors) based on the CR-39 detector foil (Radosys Ltd, *Budapest, Hungary*). Altogether, *1338 rooms in 107 schools, 540 kindergartens, 6 city halls, and 57 homes were examined at 702 locations in 11 administrative regions of Georgia once or twice for six months* from 2020 to 2022. The number of detectors exposed in each building was defined (i) by the number of floors (basement, first and second floor) and the room selected, (ii) by the duration of time children or inhabitants spend most of their time. All detectors were placed and collected personally by the project team members, sealed after exposure in a radon-proof foil pouch individually and sent to the manufacturer for evaluation. *The result obtained included the radon activity concentrations and their uncertainties.*

Figure 1. Radosys RSFV radon detector with wide-range detection (Radosys Ltd)

The summary statistics of indoor radon concentrations, separately for schools, kindergartens, city halls (only Tbilisi region) and homes in 11 administrative regions, include Min, Max, Median, AM, ASD, GM and GSD. The cumulative frequency is based on the indoor radon concentrations in all 1338 rooms.

The effective doses have been calculated according to the UNSCEAR 2000 [1] as follows:

$$E = C_{Rn} \times F \times t \times \mathrm{DCF} \quad (1),$$

where E is effective dose (mSv), C_{Rn} is indoor radon concentration (Bq m^{-3}), F is equilibrium factor between RnP and Rn (0.4), t is the time of exposure (in our case 7000 h for homes, 2000 hours for schools and kindergartens) and DCF is dose conversion factor (nSv h^{-1} (Bq m^{-3})$^{-1}$). For C_{Rn}, the arithmetic mean (AM) values from Table 1 were taken.

Results and Discussion

Summary statistics for indoor Rn concentrations and the estimated effective doses in 11 administrative regions are shown in Table 1. The regions are sorted by the population number density, and in each one, the results are presented separately for schools, kindergartens, city halls (Tbilisi) and homes. The following ranges of indoor radon concentration are obtained: 15–1189 Bq m^{-3} in schools, 2–1226 Bq m^{-3} in kindergartens and 26–335 Bq m^{-3} in homes, which is consistent with previous research [4, 5]. Figure 2 shows arithmetic means (AM) of indoor Rn concentrations in schools, kindergartens and homes for regions where the survey was performed. As seen in Table 1 and Figure 2, no concentration exceeds 300 Bq m^{-3}, the limit value of the European Commission (EC) [6], but in 55 % of cases is above 100 Bq m^{-3}, the recommended limit of the World Health Organization (WHO) [7]. The limit value of WHO [7] is exceeded in all three building categories.

The overall arithmetic mean radon concentration for all regions and all three building categories is 84 Bq m^{-3}, which is in the middle of the range summarised by Pantelić et al. (2018) [8]. However, as seen in Table 1, in several regions where only one building category was examined and where high mean Rn concentration was found, further measurements are needed, e.g., 3. Kvemo Kartli, 7. KaKheti, 9. Mtskheta-Mtianeti and 10. Racha-Lechkhumi-Svaneti.

Fig. 3 shows the cumulative frequency of indoor Rn concentration for all 1338 examined rooms. The curve roughly fits the log-normal distribution. Distinguish can be several slightly different slopes, with three the most pronounced, in the Rn concentrations ranges10–35 Bq m^{-3}, 40–200 Bq m^{-3} and 300–600 Bq m^{-3}, which indicates different origins of radon, certainly related to geology [9]. There are 86 values (6.4 %) below 10 Bq m^{-3}, which is surprisingly high, and the reason will be determined with further analysis, considering all factors that affect the indoor radon concentration. There are two values above 1000 Bq m^{-3}, also not shown in the graph (Figure 3).

Table 1. Summary statistics of indoor radon concentration and effective doses for schools, kindergartens, city halls (Tbilisi) and homes in 11 administrative regions of Georgia.

			Radon concentration Bq m^{-3}							Effective dose mSv a^{-1}
Region	Building category	No of points	Min	Max	Median	AM	ASD	GM	GSD	Adult
1 Adjara	Schools	22	15	156	58	60	33	52	1.7	0.4
	Kindergartens	32	26	180	62	72	37	65	1.6	0.5
	Homes	-	-	-	-	-	-	-	-	-
2 Imereti	Schools	9	23	348	67	98	98	73	2.1	0.7
	Kindergartens	60	11	429	75	97	73	80	1.8	0.7
	Homes	8	27	146	55	63	37	56	1.7	1.6
3 Kvemo Kartli	Schools	-	-	-	-	-	-	-	-	-
	Kindergartens	57	40	512	116	151	98	128	1.7	1.1
	Homes	-	-	-	-	-	-	-	-	-
4 Guria	Schools	-	-	-	-	-	-	-	-	-
	Kindergartens	82	16	178	56	64	37	54	1.8	0.5
	Homes	-	-	-	-	-	-	-	-	
5 Shida Kartli	Schools	6	57	470	145	194	161	145	2.3	1.4
	Kindergartens	56	39	301	72	103	69	86	1.8	0.7
	Homes	6	36	196	90	99	61	83	1.9	2.5
6 Samegrelo	Schools	-	-	-	-	-	-	-	-	-
	Kindergartens	24	12	451	50	87	115	57	2.3	0.6
	Homes	-	-	-	-	-	-	-	-	-
7 KaKheti	Schools	22	19	1189	94	155	240	100	2.3	1.2
	Kindergartens	-	-	-	-	-	-	-	-	-
	Homes	-	-	-	-	-	-	-	-	-
8 Samtskhe-Javakheti	Schools	27	19	615	102	139	121	108	2.0	1.1
	Kindergartens	30	39	813	118	169	155	128	2.0	1.3
	Homes	24	38	327	105	112	57	100	1.6	2.9
9 Mtskheta-Mtianeti	Schools	-	-	-	-	-	-	-	-	-
	Kindergartens	22	54	567	121	140	113	115	1.8	1.0
	Homes	-	-	-	-	-	-	-	-	
10 Racha-Lechkhumi-Svaneti	Schools	-	-	-	-	-	-	-	-	-
	Kindergartens	51	36	1226	73	101	158	77	1.7	0.7
	Homes	-	-	-	-	-	-	-	-	-
11 Tbilisi	Schools	14	50	269	100	118	61	105	1.6	0.8
	Kindergartens	172	2	99	22	30	24	22	2.2	0.2
	City halls	6	63	788	105	217	281	140	2.4	1.6
	Homes	19	26	335	80	123	96	94	2.1	3.8

No: number of measuring points; AM: arithmetic mean; ASD: arithmetic standard deviation; GM: geometric mean; GSD: geometric standard deviation; Min: minimum; Max: maximum

The annual effective doses ranged from 0.2 to 3.8 mSv with a mean value of 1.2 mSv a^{-1} (Table 1), a very general assessment for all three building categories. By building category, the values are as follows: 1.1 mSv a^{-1} for schools, 0.7 mSv a^{-1} for kindergartens and 2.7 mSv a^{-1} for homes. However, caution is required when using these results, as they are based on a small number of the data.

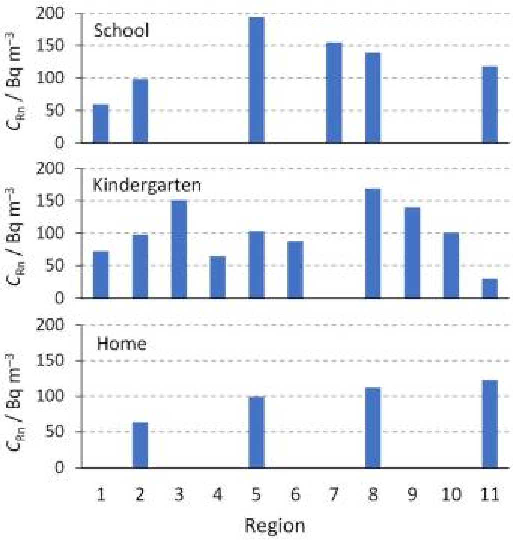

Fig. 2. Average radon concentrations in schools, kindergartens and homes in 11 regions

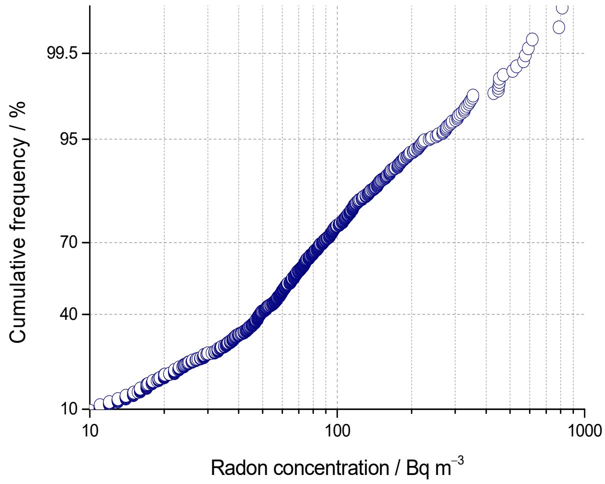

Fig. 3. Cumulative frequency of indoor radon concentrations in all places

Conclusions

The overall arithmetic mean indoor radon concentration is 84 Bq m^{-3}, considering all regions and all categories of buildings. However, higher arithmetic mean indoor radon concentration was found in several regions where further measurements would be recommended. The mean effective dose of 1.2 mSv a^{-1} was estimated, but this is a very rough approach due to the low number of data. The data obtained in this study will be further elaborated, considering all factors affecting indoor radon concentration.

Acknowledgment

As recipients of Research State Grant FN-19-22022 “Assessment of Radon Hazard Potential in Georgia”, the authors thank the Shota Rustaveli National Science Foundation of Georgia.

References

[1] UNSCEAR. Sources-to-effects assessment for radon in homes and workplaces. United Nations Scientific Committee on the Effects of Atomic Radiation // UNSCEAR 2006, Annex E. United Nations, New York, 2006.

[2] Amiranashvili A., Chelidze T., Melikadze G., Trekov I., Todadze M. Quantification of the radon distribution in various geographical areas of West Georgia. // Journal of the Georgian Geophysical Society; Issue A. Physics of Solid Earth, vol. 12A, Tbilisi, ISSN 1512-1127, 2008, pp. 65–69

[3] Amiranashvili A., Chelidze T., Melikadze G., Trekov I., Todadze M., Chankvetadze A., Chelidze L. Preliminary results of the analysis of radon content in the soil and water in different regions of west Georgia. // Institute of Geophysics, Tbilisi, ISSN 1512-1135, 2008, 60, pp. 213–218 (in Russian).

[4] Pagava S., Rusetski V., Robakidze Z., Farfán E.B., Dunker R.E., Popp J.L., Avtandilashvili M., Wells D.P., Donnelly E.H. Initial investigation of ^{222}Rn in the Tbilisi urban environment. // Health Physics, 95(6), 2008, pp.761–765.

[5] Vaupotič J., Bezek M., Kapanadze N., Melikadze G., Makharadze T. Radon and thoron measurements in West Georgia. // Journal of the Georgian Geophysical Society, Physics of Solid Earth, 15, 2012, pp. 128–137.

[6] EC, 2020. European Commission, Radiation Protection N° 193, Radon in workplaces, Implementing th3e requirements in Council Directive 2013/59/Euratom, Luxembourg. // Publications Office of the European Union, ISBN 978-92-76-10531-2.

[7] WHO, 2009. // In: Zeeb, H., Shannoun, F. (Eds.), World Health Organization. WHO Handbook on Indoor Radon: A Public Health Perspective. WHO, Geneva. ISBN 978-92-4-154767-3.

[8] Pantelić G., Čeliković I., Živanović M., Vukanac I., Nikolić Jk., Cinelli G., Gruber V. Literature review of indoor radon surveys in Europe. // Publications Office of the European Union; Luxembourg, ISBN 978-92-79-97643-8 (online), 2018; doi:10.2760/977726 (online), JRC114370.

[9] Kapanadze N., Melikadze G., Tchankvetadze A., Todadze M., Jimsheladze T., Gogichaishvili Sh., Chikviladze E., Chelidze L., Vaupotič J. Radon in soil gas in crystalline shales and volcanic grounds in selected regions of Georgia. // 16th International workshop GARM - Geological aspects of Radon risk mapping; September 19th – 21st, 2023, Prague, Czech Republic.