Original scientific papers

UDK 551.510.7:546.296]:519.876.5
doi: 10.7251/COMEN1701028C

COMPARISON OF RADON CONCENTRATION MEASURED BY SHORT-TERM (ACTIVE) AND LONG-TERM (PASSIVE) METHOD

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Abstract: Measuring of radon concentration in an indoor space in most cases is carried out by passive method by means of track detectors (CR – 39) with the period of exposure of six or twelve months. On the other hand, active method is less used, semiconductor detectors (Rad 7) with a direct reading of radon concentration and period of measurement of 7 days. The aim of this work is to compare the results of passive and active method in order to determine Pearson correlation coefficient between these two methods.

Keywords: Radon, radon concentration, CR – 39 detectors, Rad 7, passive method, active method, Pearson coefficient.

1. INTRODUCTION

Under the normal conditions (if we exempt accidental irradiation or medical application of radiation), radon and its descendants provide the highest individual contribution to the annual effective equivalent dosage that the population is exposed to from ionizing radiation (over 50 %) [1]. At the same time, radon concentration is changed during the day, month, seasons and geological activities and that is why radon presents one of the most variable factors that influence this dosage. Besides the concentration of activities of natural radionuclides in soil, first of all of uranium natural line (U-238) out of which the radon stems from, the soil porosity is one of the main factors that influence the radon emanation. Due to that, the radon can penetrate in higher concentrations into the buildings constructed from material with the high contents of natural radionuclides or which are not sufficiently well isolated and are within the area of radioactive natural anomalies (ie. in the area with naturally increased contents of radionuclides in the soil). These concentrations in some cases can be identical with the activity of radon in unit volume of air in uranium mines. Because of the fact that radon concentrations in air oscillate, on the basis of the geological foundation, building characteristics, meteorological conditions, it cannot be established which buildings are more and which are less jeopardized. That is why systemic measuring of radon in air, comprising statistically sufficient number of buildings, are the basis of all further researches according to which distribution of radon concentration can be determined, effective dosage that the population receives from ionizing radiation from the nature can be assessed, and areas with increased radon risk can be identified. Radon is the agent for which it is proved that it causes lung cancer in humans, and is classified into IA class according to World Health Organization in 1996 (WHO) [2]. International Commission on Radiological Protection (ICRP) gave the recommendations on acceptable level of radon in apartments and in work places. Primary schools present the environment in which the adults and children live and stay spending there a significant period of time. That is why the research of exposure of population in schools was implemented in the majority of European countries presenting an important component of national programs for radon in the assessment of exposure to radon of population of particular countries [3].

2. METHOD AND EXPERIMENTAL WORK

Measuring radon concentration was carried out by means of continuous radon monitor RAD 7 (Durridge company, USA), that is functioning on the

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principle of semiconductor α-detector converting the energy of α-particles directly into an electric signal. This enables us to determine which isotype is a product of radiation (^{218}Po, ^{214}Po,...) so that radon can be differentiated from its descendants, radon from thoron and signal from murmur [8]. Besides the multi-day measurements with different times of reading, the instrument has also an option of „sniffing" which enables that within 5 minutes we obtain a framework concentration of radon at selected measuring spot. Sensitivity of an instrument is 0,5 [pCi/liter], and the scope is 4 – 750000 Bq/m^3. Internal memory is capable to remember the values of 1000 last radon concentrations. Flow of air pump is 1 l/min, and the air that is sampled passes through the driers and the filter that are located in front of the interaction chamber. The instrument possesses RS232 port for communication with the computer, autonomous supply, IC printer and many other conveniences that significantly facilitate measuring of the radon concentration. [4]

Measuring the radon concentration was also carried out by means of RSKS detector consisting of CR-39 film that is placed in conductive cyllindric diffuse chamber made of plastics (cellulose esters and polycarbonates). Solid nuclear track detector CR-39 is placed in the bottom of the chamber. After exposure of the detector and their return to laboratory, they are opened and after that microfilms are separated from diffuse chamber in order to be prepared for chemical processing. Tracks of damage (latent tracks) can be made visible under the microscopic activity of various agents that corrode the place of damage faster than surrounding undamaged material, and as a result of this difference in the speed of corrosion we obtain expanded track. Depending on the energy, charge and size of ion, latent track can be of a diameter of 1-10 nm [5]. By the procedure of corrosion, tracks become larger, with diameter within the interval 10 - 20 μm [6]. Corrosion of microfilms is carried out in a corrosion bowl. Detectors are chemically developed within 1 hour in 6.25 normal solution of NaOH at the temperature of 98 ^{o}C. Once they are extracted from the bathroom, detectors are rinsed, first time with distilled water and then tap water and they are left for 30 minutes in 2% water solution (distilled water) of acetic acid in order to interrupt further development of tracks. After that, detectors are rinsed again and are left to dry. After drying of detectors, tracks are counted [5,6].

Measuring was carried out in twenty-five schools that are located in the narrow city proper of Banja Luka and are built from similar materials within the period from 1953 to 1973. Premises that are located on the ground floor are selected as measuring spots. Rad 7 was placed on the floor so that air was sampled at the height of 0.5 m. Readings were carried out every 2 hours, ie. 84 times for seven days. Air humidity in the instrument after dryer did not exceed 10%, and temperature of premises was between 17 ^{o}C and 25 ^{o}C. Detectors CR-39 were placed on an internal wall of the premise at the height of 30 cm from the ceiling and were exposed for a year. It is important to point out that Rad 7 and CR-39 detectors were placed in the same premise.

3. RESULTS OF MEASUREMENTS

Results of radon concentration measured by active method (Rad 7) and passive method of measurement (CR – 39 detectors) in 25 primary schools of the City of Banja Luka are shown in Table 1.

Table 1. Results of measurement by active and passive method

No.	Name of the school	Active method (7days) [Bq/m^3]	Passive method (1 year) [Bq/m^3]
1	Mladen Stojanović Bronzani Majdan	415	336
2	Branislav Nušić Toplice	157	253
3	Ivo Andrić Centar	401	86
4	Branko Radičević Starčevica	122	129
5	Petar Petrović Njegoš Mejdan	59	48
6	Ivan Goran Kovačić Budžak	45	85
7	Vuk Karadžić Borik	51	79
8	Milutin Bojić Potkozarje	67	91
9	Sveti Sava Lauš	154	63
10	Ćirilo i Metodije Piskavica	67	58
11	Đura Jakšić Šargovac	41	63
12	Stanko Rakita Vrbanja	35	43
13	Branko Ćopić Borik	112	51
14	Jovan Cvijić Centar	36	56

No.	Name of the school	Active method (7days) [Bq/m^3]	Passive method (1 year) [Bq/m³]
15	Dositej Obradović Mejdan	42	51
16	Miroslav Antić Bistrica	76	65
17	Milan Rakić Karanovac	51	66
18	Vojislav Ilić Krupa na Vrbasu	84	51
19	Georgije Rakovski Nova Varoš	50	31
20	Desanka Maksimović Dragočaj	42	49
21	Zmaj Jova Jovanović Hisete	28	33
22	Jovan Dučić Zalužani	32	38
23	Aleksa Šantić Malta	119	53
24	Borisav Stanković Budžak	72	73
25	Petar Kočić Han Kola	119	45

If we compare the results, it can be seen that in 14 schools, the value of radon concentration measured by passive method has larger value than the results measured by active method. In four schools, concentrations measured by active method are twice higher, and in one school the value is five times higher in relation to concentrations measured by passive method. Graphic display of the measuring results of radon concentrations by active and passive method shown in Table 1 is presented in Figure 1.

Descriptive statistics of the radon concentration measured by active and passive method in schools at the territory of the City of Banja Luka is shown in Table 2.

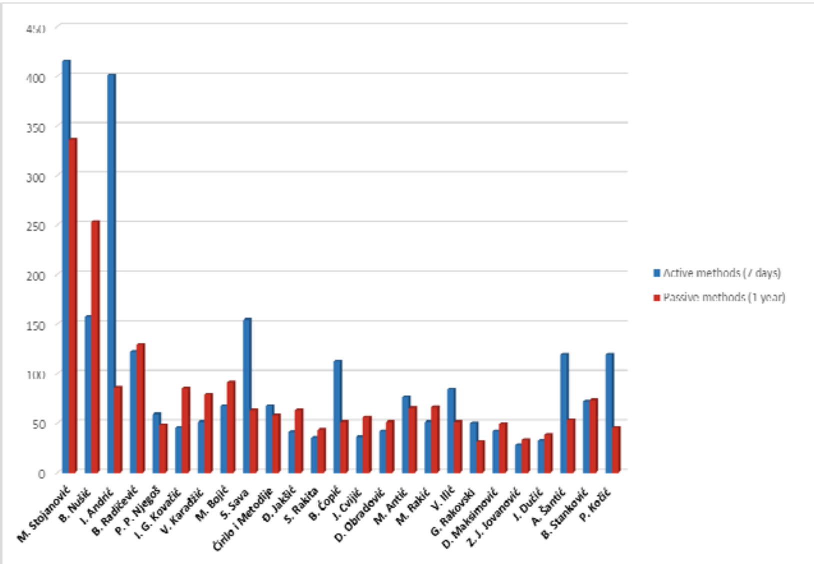

Figure 1. Graphic display of the measuring results of radon concentration by active and passive method

Table 2. Descriptive statistics of radon concentrations measured by active and passive method

	Active method	Passive method
Number of measurings	25	25
Minimum	28	31
Median	67	58
Maximum	415	336
Arythmetic median value	99	80
Standard deviation	100	69
Standard error	20	14
Geometric mean value	73	66
Geometric standard deviation	2,02	1,72

Histograms of measured radon concentrations in schools fitted with log-normal function for measuring are shown in Figure 2.

Besides visual assessment, expected log-normal distribution was tested by applying Kolmogorov-Smirnov test (KS) at 95% reliability level. In case when error probability *p is* higher than 0,05, confirmed is the hypothesis set in advance that there is a statistically significant difference between experimental and empirical distribution of results. In Table 3, presented are the parameters of log-normal function (μ, σ), error probability of *p* KS test and confirmation of distribution significance for both groups of results of radon concentration.

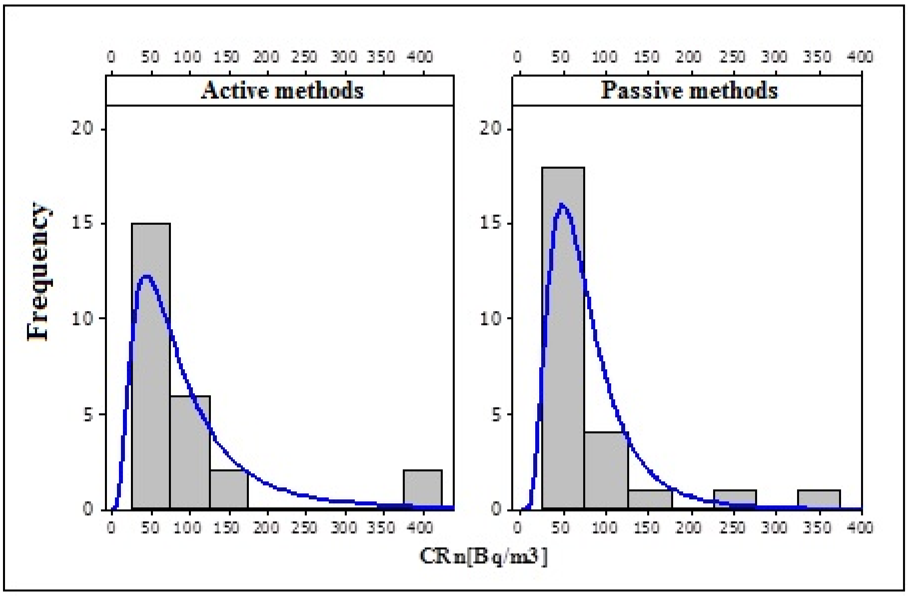

Figure 2. Histograms of measured radon concentration

Table 3. Parameters of log-normal function, by probable error (p) and significance of KS test for two groups of measuring of radon concentrations

	μ	σ^2	Kolmogorov-Smirnov *p*	log-normal distribution
Active method	4,297	0,512	0,751	Statistically significant
Passive method	4,187	0,306	0,405	Statistically significant

For the needs of correlation analysis, in order to decrease the influence of extreme values to the final outcome of linear regression analysis, calculated were natural logarithms of measured concentrations. Hypothesis that the logarithms of radon concentrations have normal distribution was confirmed for both measuring groups (KS, p>0,05). Cumulative frequency of logarithmed radon concentration with 95% of significance limits are presented in the Figure 3.

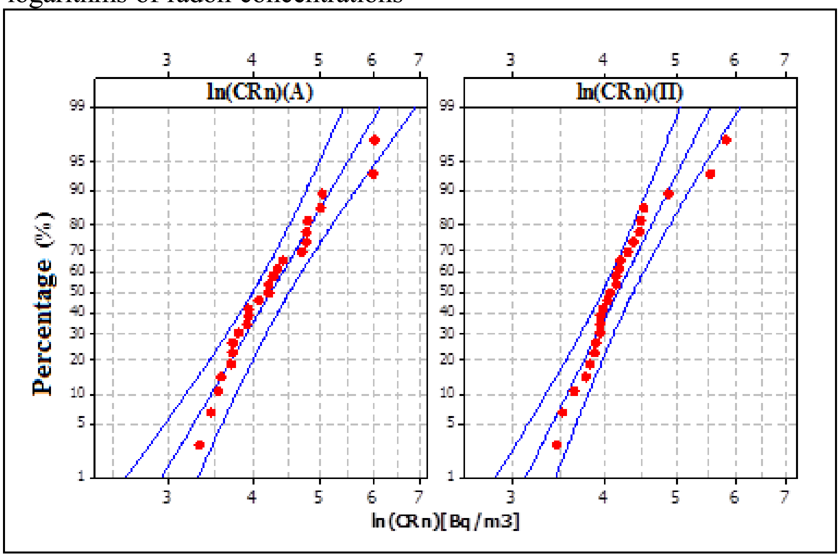

Figure 3. Cumulative frequency of logarithmed radon concentration with 95% of significance limits

After „normalization" of results and check of their homogeneity applying Bartlett test (B, p>0,05), examined was correlation between the results of radon concentration. The model of parametric linear regression (LR, p<0,05) was applied.

Degree of correlation between the results of radon concentration expressed through Pearson determination coefficient (R^2) is shown in Table 4.

Table 4. Determination coefficient

R^2			
		ln(CRn) (A) (7 days)	ln(CRn) (П)
	ln(CRn) (A)	1	0,653
	ln(CRn) (П)	0,653	1

4. CONCLUSION

Degree of correlation of results of concentration of ^{222}Rn measured by active method (average weekly concentration) and passive method CR-39 detectors (average annual concentration), expressed through Pearson determination coefficient (R^2) is 0,65. Out of Pearson determination coefficient (R^2), it can be seen that comparison of passive and active method did not offer a high level of correlation. The main reason of low level of correlation are seasonal variations of radon that have large influence to the results of weekly measurings during the year. These researches have shown that if we want to carry out assessment of annual effective dosage, we have to give advantage to measurings of the radon concentration by passive method.

5. REFERENCE

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ПОРЕЂЕЊЕ КОНЦЕНТРАЦИЈА РАДОНА МЈЕРЕНИХ КРАТКОРОЧНОМ (АКТИВНОМ) И ДУГОРОЧНОМ (ПАСИВНОМ) МЕТОДОМ

Сажетак: Мјерење концентрација радона у затвореном простору у већини случајева врши се пасивном методом помоћу траг детектора (Cr – 39) са периодом изложености шест или дванаест мјесеци. С друге стране, мање се користи активна метода, полупроводнички детектори (Рад 7) са директним очитавањем концентрација радона и периодом мјерења седам дана. Овај рад има за циљ поређења резултата пасивне и активне методе како би се одредио Пирсонов коефицијент корелације између ове двије методе.

Кључне ријечи: Радон, концентрација радона, Cr – 39 детектори, Рад 7, пасивна метода, активна метода, Пирсонов коефицијент.