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MEASUREMENT OF GAMMA DOSE RATE IN HOSPITALS FOR REHABILITATION IN BULGARIA

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Summary: The objective of this study was to evaluate the indoor gamma dose rate in 17 inspected hospitals for rehabilitation where the radon measurements were conducted and to give a more comprehensive evaluation of the total exposure dose.

The gamma dose rate in the air was measured in 355 rooms in 17 inspected hospitals for rehabilitation on the territory of Bulgaria. The maximum parameter value was 0.390 μSv/h and the minimum value was 0.06 μSv/h with the 0.157 μSv/h arithmetic mean (standard deviation - 0.160). The gamma dose rate was within the natural variations of the parameter in buildings. Direct measurements of radon were conducted, and the results ranged from 12 Bq/m^3 to 3920 Bq/m^3. The relationship between the two parameters was examined. A weak correlation between gamma dose rate and indoor radon concentration was found. The measurement of a gamma dose rate could be a useful parameter for carrying out radon workplace control.

Keywords: gamma dose rate, hospitals, radon, direct measurement.

1. INTRODUCTION

Natural radioactivity is an integral part of our environment. Humans are exposed to different levels depending on natural radioactive elements present in rocks, soil, and water within the region. The levels of radioactivity form various public dose rates. Accumulated indoor radon and its products are the largest natural source of public exposure, accounting for approximately half the total effective dose from all sources [1]. Some human activities, such as manufacturing, mineral extraction, or water processing could technologically enhance the natural background by concentrating the radionuclides as ^{222}Rn, ^{226}Ra, and ^{228}Ra [2,3]. Water supplies contribute a small part to the indoor radon exposure but can be the dominant source in areas where the radon content of groundwater is unusually high [4]. The hot spring and its surrounding area are an example of an elevated source of natural radiation. The water from the hot spring is used extensively for balneotherapy and in thermal baths. In thermal spas, the exposure to natural radiation mainly occurs due to radon dissolved in water depending mostly on the concentration of uranium in the surrounding rock as well as on the circulation of water [3]. Radon could be released to the indoor air, and together with its solid decay products expose the people to it. Although the radon exposure will be of much higher magnitude, the workers and users of the water for therapeutic purposes could be exposed also from external gamma radiation [5]. In the field of radiation protection, there are the adopted basic safety standards for protection against the danger arising from public exposure to ionizing radiation, including the operation and use of sources of natural radiation, such as thermal spas.

Bulgaria has many places, where the mineral water is used for rehabilitation and thermal baths and spas. These places are planned in National Radon Action Plan for investigation. The observation was started in the Specialized Hospitals for Rehabilitation – National Complex EAD (SBR – NK EAD) during 2019.

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2. MATERIALS AND METHOD

The survey was carried out in 17 buildings at 12 the Specialized Hospitals, which use mineral water for treatment located on the territory of the whole country from March 2019 to February 2020. The measured buildings were given a certain code: Narechenski Bani - building 1; Momin Prohod - buildings 2 and 3; Banya - building 4; Hisarya - building 5; Pavel Banya - buildings 6 and 7; Varshec - buildings 8 and 9; Bankya - building 10; Kyustendil - buildings 11 and 12; Sandanski - building 13; Velingrad - buildings 14 and 15 and Ovcha Mogila - building 16. The surveyed sites by settlements are shown on the map (Figure 1). In the hospitals, natural and remedial factors such as the climate, mineral water, curative mud in combination with instrumental physiotherapy and kinesitherapy are being applied. Most of the objects (11 units) of the department are located in mountainous areas, except for one in the Danube plain (the village of Ovcha Mogila).

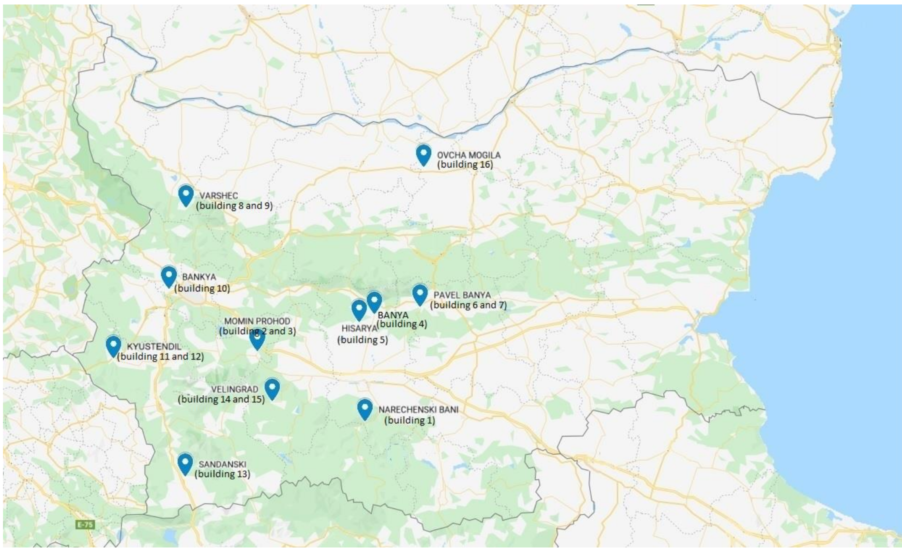

Figure 1. Measuring sites on the territory in Bulgaria

The gamma dose rates were measured using the Geiger Muller counter type RADOS RDS-110 dosimeter. The dosimeter measuring range is from 0.05 μSv/h to 100 mSv/h in the energy range of 50 keV to 1.25 MeV. The detector is suitable for environmental gamma radiation measurements. It covers the majority of significant gamma radiations emitted from terrestrial sources. The calibration accuracy is ± 2% (2σ), according to the Calibration Certificate from 2019. A one-minute integrated count technique is a practical survey procedure for equipment. The relative uncertainty of the method was assessed to be 12%. The gamma dose rate was measured following the accredited procedure. The indoor gamma dose rate measurements were taken in air 1 m above ground at each premise in the object. About 10 readings were taken at each point, and the ambient mean was considered as the representative value of the gamma dose rate for the objects.

The method of direct radon measurements is based on the continuous sampling of a volume of air, pre-filtered and representative of the studied atmosphere. Indoor radon concentration values can vary on daily basis, depending on several factors: thermo-hygrometric conditions, the strength of the radon source in the underlying bedrock, species of season, soil types, pressure changes created by the building as well as the level of ventilation and occupancy itself also contribute significantly [6–10]. A professional AlphaGUARD PQ 2000 monitoring system and TERA system were used to perform direct radon measurements (Genitron, Germany).

The device is not affected by high humidity and vibration. Its range has a linear dependence from 2 to 2,000,000 Bq/m^3. DataEXPERT is used for graphical processing and presentation, evaluation, and storage of the measured spectra. The values are registered for 10-min intervals over approximately 12-24 hours.. The instrument is calibrated to reference in accredited.

AlphaE is based on a silicon diode diffusion chamber, has been developed by a cooperation of the Munich Helmholtz Centre and Saphymo GmbH, Germany. The detector provides a wide measurement range up to 10 MBq/m^3 and is sufficiently sensitive for reliable measurements below 100 Bq/m^3.

TERA System consists of Central Unit and probes. The probe measures in an autonomous and time- continuous way. It processes results at given intervals (default 4-minute intervals) and it counts the moving average of radon concentration value at an interval of 1 hour. It also counts the moving average of radon concentration value at an interval of 24 hours. The probe saves time records of these radon concentration values within internal memory (typically at an interval of 1 hour).

The instruments are also equipped with sensors for temperature, relative humidity, and atmospheric pressure. Measurement of indoor radon concentration was performed continuously at 41 selected locations in the hospitals. In 16 rooms the measurements were performed with AlphaGUARD, in 23 places with system TERA and in 2 premises with Alpha E.

The data were analyzed statistically to construct a model, that would be applicable for investigation of the thermal spas and that explained the behavior of this variable with radon concentration. From the data collected for the radon concentration in indoor air, it was possible to evaluate the relation between these two parameters. SPSS, version 20 was used for the analysis. Descriptive statistics and non-parametric analysis (Krushkal Wallis and Mann Whitney Tests), level of significance $p<0.05$ were carried out.

3. RESULTS AND DISCUSSION

Descriptive statistics (arithmetic mean - AM, standard deviation STD, geometric mean - GM) of the results for gamma dose rate in the premises of hospitals present in Table 1. Gamma dose rate was measured in two types of premises in hospitals, where the water is used for procedure and others. Descriptive statistics of the results according to the types of premises are given in Table 1.

Table 1. Descriptive statistics of gamma radiation dose rate in the premises of SBR-NK

Descriptive parameters	*Total premises*	*Other premises*	*Premises with water procedure*
Number of measured rooms	355	180	175
Arithmetic mean, µSv/h	0.158	0.144	0.150
Standard deviation	0.058	0.037	0.160
Median, µSv/h	0.160	0.150	0.040
Geometric mean	0.141	0.139	0.145
Minimum value, µSv/h	0.070	0.070	0.070
Maximum value, µSv/h	0.390	0.250	0.390
CV, %	37	26	27

The dose rate of gamma radiation is within the natural variations of the parameter in buildings. Usually, the gamma dose rate in buildings is higher than the dimensions outside. The maximum value of the parameter was measured in the building of the Narechenski Bani - building 1 (0.390 µSv/h), followed by that in buildings 3 and 4 in village Banya, Karlovo municipality, Plovdiv district (0.29µSv/h). Such kind of values and higher were reported in a study conducted in Portuguese thermal spas (0.645µSv/h) [11–13]. The variations of the gamma dose rate by buildings are presented in Figure 2. Regarding the variation of the gamma radiation dose rate data, it was found in the buildings with codes 3, 4, 9, and 10 that the values obtained have no variation compared to the buildings 1 in Narechenski Bani and 2 in Momin Prohod. In those buildings, the high radon concentration was measured. The Krushkal Wallis Test, which was applied, shows a statistically significant difference between measurements in different buildings, $p<0.001$.

To study this variation in more detail, the gamma dose rate results in buildings are divided into two groups according to the measured radon values. A non-parametric Mann–Whitney Test was applied. The result is not significant, $p < 0.05$ (MU, $p=0.084$). On the other hand, the premises in the hospitals are divided into two groups to investigate the difference between them: those in which water is used for procedures (water procedures) and other premises (Figure 3). Premises, where the water is used for procedures are swimming pools, baths, tangents, etc. Other premises are kinesitherapy, acupuncture, paraffin therapy, administrative, etc. A statistically significant difference was not found between the results by applying a Mann–Whitney U test (MU, $p=0.54$).

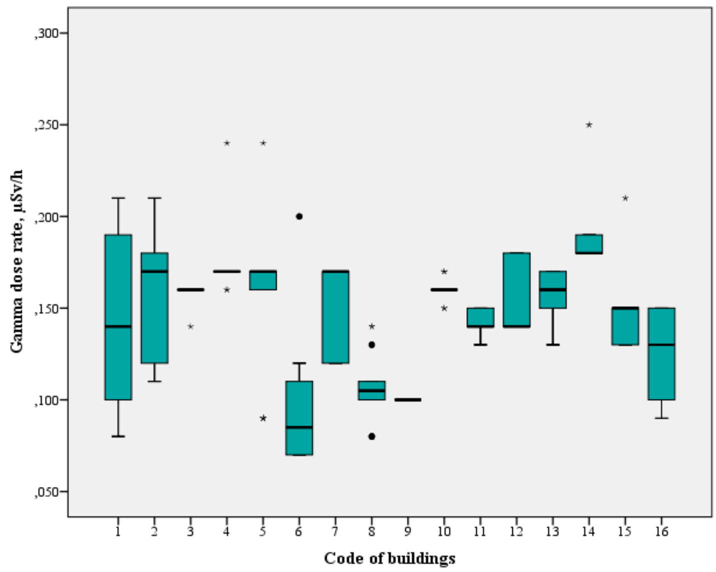

Figure 2. Variations of gamma dose rate by buildings

The lack of a statistically significant difference could be explained because the source of radon in buildings is thermal water, which does not significantly affect the gamma dose rate. The main source of gamma radiation in the building is the building materials from which it is built [11].

Direct measurements of the radon concentration were performed in the premises with water procedures. The results are presented in Figure 4.

In two buildings of hospitals with code 1 in Narechenski Bani and with code 2 in Momin Prohod high values of radon concentration above the reference level of 300 Bq/m^3 were found. The relation between direct measurements of radon concentration and gamma dose rate was statistically analyzed and no link was found. The direct measurements track the daily variations of radon, through which the operation mode of the ventilation system could be established, as well as the radon concentration during working hours.

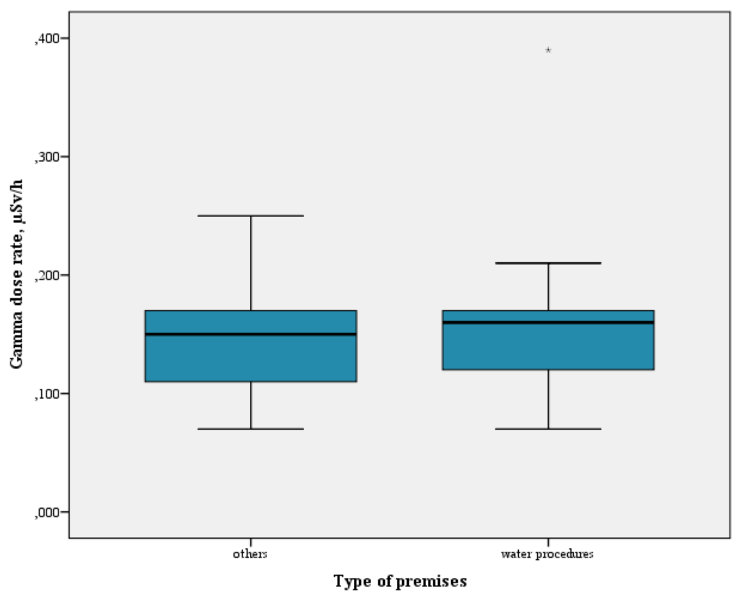

Figure 3. Gamma dose rate in premises with water procedures and other premises

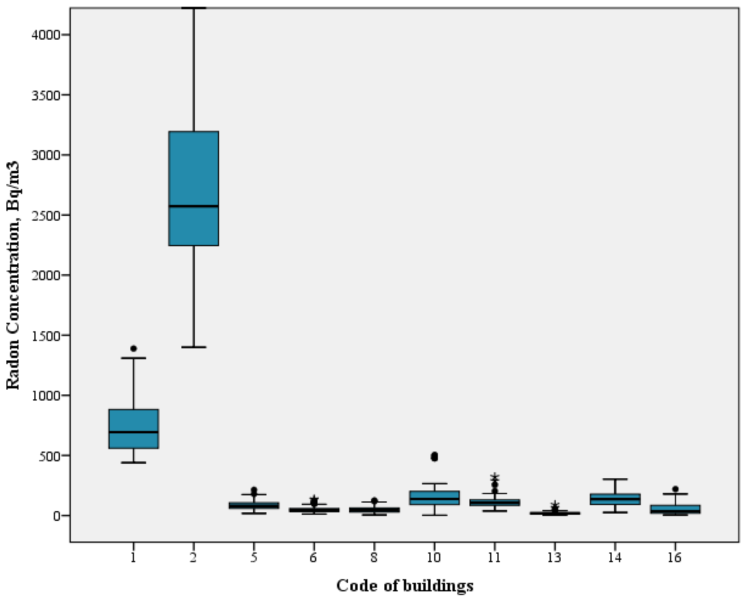

Figure 4. Radon concentration in premises with water procedures in hospitals buildings

To continue examination whether there is a relationship between radon concentration measured with passive detectors and gamma dose rate the linear regression model was applied. A linear relationship (association) was established between the two studied parameters with a coefficient of significance of the model $p=0.003<0.05$. The correlation coefficient is only 2.5%, which shows that a radon concentration variance could be predicted from gamma dose rate results. Our results are also confirmed by research conducted in other countries: a study in Italy finds low dependence between radon concentration and gamma dose rate measured in dwellings due to building materials and materials used for flooring and walls [14,15]. The weak association is in line with a study done in Naples, where the same conclusions were reached [16].

4. CONCLUSION

The gamma dose rate was measured in 17 buildings during the investigation of radon concentration in 12 hospitals for rehabilitation. There are not detected too high values of gamma dose rates in observed premises. Therefore, the contribution of the external dose to the exposure of people is negligible. The variation of the parameter is considered and the results are grouped by type of the procedure premises (therapy with water and without water). No statistically significant difference was found, indicating that the dose rate is not affected by water use in therapy. The analysis of the relation between radon measured with passive detectors and gamma dose rate shows the linear regression with a low correlation coefficient only 2.5%. The investigation of gamma dose rate and radon with integral, direct measurement would be useful in observation of the building with public access for assessment of people exposure.

5. ACKNOWLEDGEMENTS

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МЈЕРЕЊЕ НИВОА ГАМА ЗРАЧЕЊА У БОЛНИЦАМА
ЗА РЕХАБИЛИТАЦИЈУ У БУГАРСКОЈ

Сажетак: Циљ овог истраживања био је процијенити ниво гама зрачења у затвореном у 17 прегледаних болница за рехабилитацију у којима су проведена мјерења радона и дати опсежнију процјену укупног нивоа изложености.

Ниво гама зрачења у ваздуху измјерен је у 355 соба у 17 прегледаних болница за рехабилитацију на територији Бугарске. Максимална вриједност параметра била је 0,390 μSv/h, а минимална вриједност 0,06 μSv/h са аритметичком средином од 0,157 μSv/h (стандардна девијација – 0,160). Ниво гама зрачења био је унутар природних варијација параметра у зградама. Извршена су директна мјерења радона, а резултати су се кретали од 12 Bq/m3 до 3920 Bq/m3. Испитана је повезаност између два параметра. Пронађена је слаба корелација између нивоа гама зрачења и концентрације радона у затвореном простору. Мјерење нивоа гама зрачења могло би бити користан параметар за провођење контроле присуства радона на радном мјесту.

Кључне ријечи: ниво гама зрачења, болнице, радон, директно мјерење.

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