INDOOR RADON MEASUREMENTS IN BACĂU COUNTY*

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In this paper are presented the results of indoor radon survey in Bacău County. Radon measurements were made in 37 dwellings by using CR-39 nuclear track detectors exposed for approximately three months, during spring and summer. The study area contains locations from different parts of Bacău County, which was divided in 60 square cells of 10 x 10 Km out of which 20 (33%) were fully covered. Moreover, the radon detectors were placed only in dwellings, most of them situated in rural areas.
The measured radon concentrations indicating a log-normal distribution, confirmed by the D'Agostino-Pearson test (K^2 = 0.88, p = 0.64). The average of indoor radon concentrations for Bacău County was found to be 58 Bq/m^3. The values recorded in the study area vary from 18 to 180 Bq/m^3, which is below the recommended action limit of ICRP.

Key words: radon map, house structure, passive dosemeters.

1. INTRODUCTION

Radon is a radioactive gas that results from ^{238}U, which can be found in soil and building materials [1].

Depending on the geological and geophysical aspects, as well as the features of building materials, radon can migrate into the indoor air, which can lead to an increase in radon concentrations. The source of radon in residential air can be, in most situations, explained by its presence in the underground soil and by the convective transport that helps its accumulation in the indoor air. In the absence of a paving between the ground and the building, the diffuse transport can also have an important contribution in the growth of indoor radon concentration, as a result to the different concentrations in the soil and the room [2].

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Due to the fact that *Joint Research Center* (JRC) of the European Union is planning to map the indoor radon concentrations in the entire Europe, it is highly recommended to evaluate the indoor radon levels, as well as to study the factors that could influence those levels.

Therefore, the present paper is planning to measure the residential radon concentrations in Bacău County in order to achieve the first indoor radon map for this county, using the grid cells provided by JRC. Moreover, the impact of the house structure (type of floors, windows, the presence or absence of concrete floor capping) on the indoor radon concentration will be studied.

2. MATERIAL AND METHODS

Indoor radon measurements were made in 37 dwellings of Bacău County and were carried out using CR-39 nuclear track detectors, that were exposed for three months (April to June 2012). The detectors were placed at least 1 m from the floor and away from doors and windows. All detalis regarding the measurement protocol have previously been described [3, 4]. In order to place the nuclear track detectors we approached a door-to-door method, thus 97% of the CR-39 detectors being recovered. Most of the 37 dwellings under surveillance were chosen to express an adequate knowledge of the radon distribution in rural areas and 4 (11%) of these houses were situated in cities.

Also a questionnaire was provided to the inhabitants of each surveyed house in order to collect relevant information about factors relating to measurement site as building structure, building materials, living habits, etc. The presence of floor capping was also taking into consideration when performing the statistical analysis.

For the radon mapping, Bacău County was divided in 60 square cells, each covering an area of 10 x 10 km. For the cells under surveillance, the dwellings were chosen randomly and they cover the central, north-western and south-western areas in Bacău County.

The statistical analysis of the recorded levels of indoor radon concentrations was made using Minitab 16 and GraphPad Prism 5. The comparison between samples was made with t-test (two groups), for the log-transformed data, if the normal distribution was confirmed by D'Agostino-Pearson test and the variance was homogeneous (Barteltt's test). If the distribution of the log-transformed data was non-normal, then the non-parametric Mann Whitney test (two groups) was used. The significance level was chosen at $\alpha = 0.05$. The indoor radon map of Bacău County was plotted with Surfer 10 and ArcGIS 9.0 on the reference grid 10 km x 10 km developed by JRC [5].

3. RESULTS AND DISCUSSION

The overall distribution of indoor radon concentrations is plotted in Fig. 1, the measured values indicating a log-normal distribution, confirmed by the D'Agostino-Pearson test ($K^2 = 0.88$, $p = 0.64$). Indoor radon concentrations range from 18 to 180 Bq/m^3, which means that they all are below the recommended action limit of ICRP, 2010 [6]. The average indoor level was found to be 58 ± 40 Bq/m^3. The annual average for Bacău County, estimated with the seasonal correction factors [7] was 67 ± 46 Bq/m^3, which is about 2 times lower than the average value of 126 Bq/m^3, computed for Romania by our group in previous studies [4].

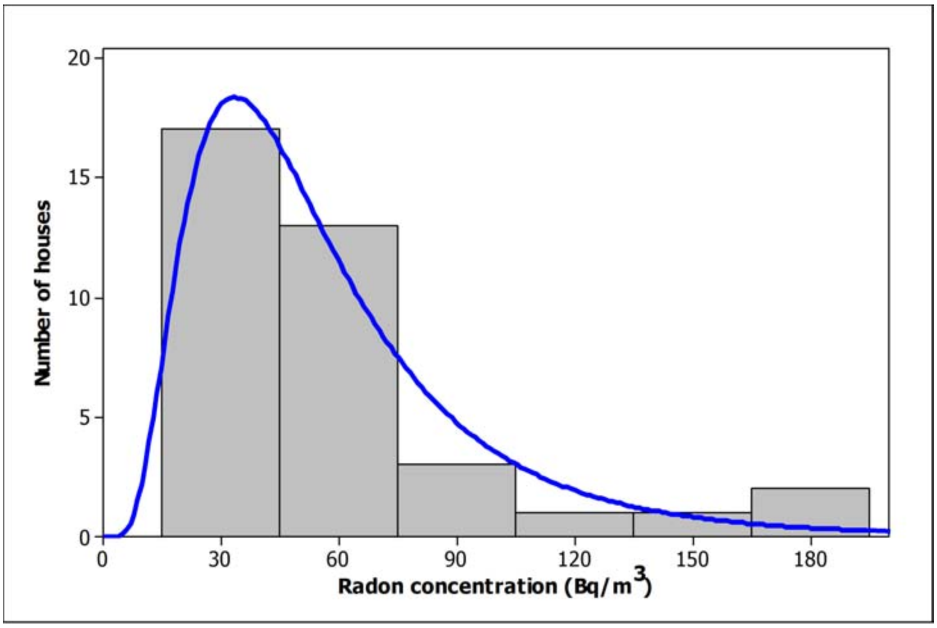

Fig. 1 – The log-normal distribution of radon concentration for the 37 investigated houses.

The indoor radon map was plotted on the reference grid 10 km x 10 km developed by JRC of the European Commission. Bacău County was divided in 60 square cells out of which 20 (33%) were covered based on 37 radon measurements (Fig. 2). The average radon concentrations slightly vary from one cell to another, but they do not follow a specific pattern that could be used for further examination. Only for 10 % of the filled cells the arithmetic mean was above 100 Bq/m^3. The formations under the surveyed areas contain Quaternary – Pleistocene clay, sand and gravel as well as Paleocene limestone, chalk, shale and sandstone.

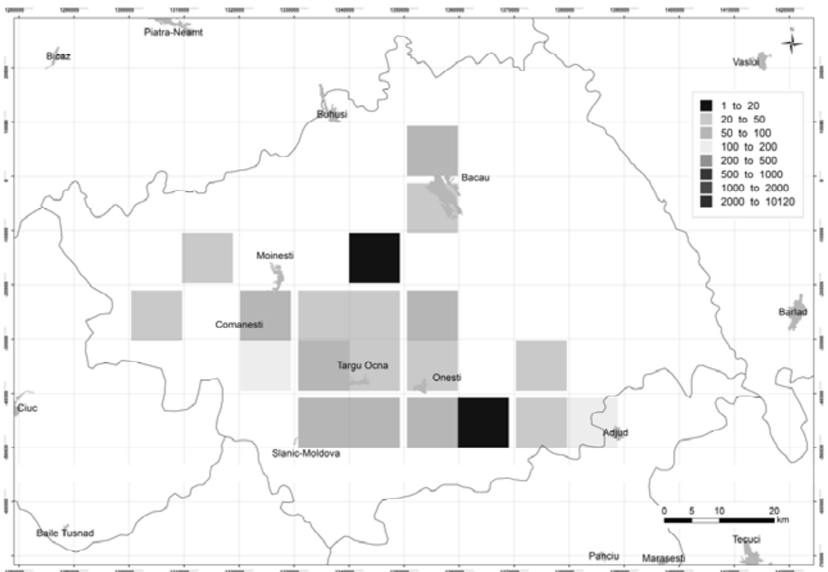

Fig. 2 – Average mean for indoor radon levels in the surveyed cells from Bacău County.

Another comparison of the recorded values was made based on the type of materials that were used in the construction of the surveyed dwellings. As it can be seen in Table 1, the maximum indoor radon concentration was found in brick houses (75 Bq/m^3), while the smallest concentration was recorded in wood houses (45 Bq/m^3). The highest coefficient of variation (86%) belongs to concrete houses, while the smallest one (4%) was obtained from adobe dwellings, among others, due to the small number of measurements.

Table 1

Descriptive statistic of radon concentrations based on the building materials

Building materials	**Number**	**AM (Bq/m^3)**	**SD (Bq/m^3)**	**GM (Bq/m^3)**	**GSD (Bq/m^3)**	**CV (%)**
Adobe	3	58	3	58	1.0	4
Bricks	13	75	55	60	2.0	73
Concrete	3	59	51	46	2.2	86
Wood	9	45	22	40	1.6	48
AAC/Other	9	46	24	41	1.6	53
Total	**37**	**58**	**40**	**48**	**1.8**	**68**

AM = arithmetic mean, SD = strandard deviation, GM = geometric mean, GSD = geometric standard deviation, CV = coefficient of variation.

In the same statistical analysis we were able to see a small impact that windows have on indoor radon concentrations. Therefore, Table 2 shows the recorded values in houses with simple windows and in those with thermo-isolated ones. The difference between the indoor radon concentrations in the two groups can be taken into account, but it is not statistically significant by applying unpaired t test on the log-transformed data (p = 0.4). This small difference can be explained based on the isolating properties of each type of window. Simple windows do not isolate the room to well, as they rarely close properly, therefore, fresh air could constantly infiltrate into the house.

Table 2

Descriptive statistic of radon concentrations based on windows type

Windows type	Number	AM (Bq/m^3)	SD (Bq/m^3)	GM (Bq/m^3)	GSD (Bq/m^3)	CV (%)
Simple	24	53	32	45	1.8	60
Thermo-isolated	13	67	51	54	2.0	76

Another analysis was made based on the concrete floor capping. Concrete floor capping refers to a thick layer of concrete that it is poured under the floor, in order to protect and isolate the house. The application of Mann-Whitney test demonstrated that the difference between the radon concentrations in the presence or absence of the concrete floor capping (Fig. 3) is statistically significant (p = 0.04). This can be explained if we take into consideration the fact that the concrete layer underneath the original floor has a major role in protecting the floor of radon from soil.

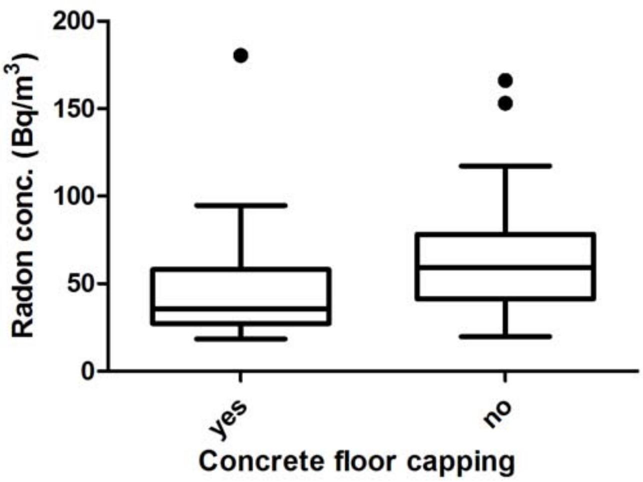

Fig. 3 – Variability of radon concentration by presence/absence of floor capping in Bacău County, showing 25th, 50th (median) and 75th percentile. The outliers are represented by outside dots.

This paper also studied the indoor radon concentrations based on the type of floor, as the surveyed dwellings had wooden, sandstone and parquet floors. The considerable difference between the houses with wooden flooring and those that have sandstone flooring can be explained based on the followings: wooden flooring whether it is parquet or simple wood, often has cracks and small spaces between the joints, while sandstone is mounted on the floor in a certain way that the radon from soil cannot break through. Fig. 4 shows that this difference is quite noticeable.

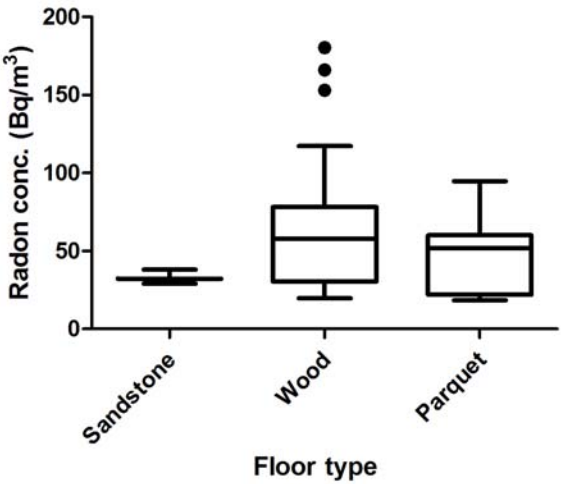

Fig. 4 – Variability of radon concentration by flooring type in Bacău County, showing 25th, 50th (median) and 75th percentile. The outliers are represented by outside dots.

4. CONCLUSIONS

This study shows the indoor radon concentrations in 37 dwellings situated in Bacău County. Taking into consideration the exposure period and the recorded levels, it can be said that the area in Bacău County has radon concentrations below the recommended action limit of ICRP [6]. Therefore, there is no need for precaution methods or any use of supplementary ventilation in any of the selected houses.

The building materials can slightly influence the indoor radon concentrations. Brick and concrete houses show increased radon levels, while wood and adobe houses present low radon concentrations. Moreover, the floors have also an impact on radon concentrations as well as the existence of concrete floor capping.

The soil characteristics under the dwellings might be the main reason for the indoor radon concentrations, but for now, it is only a hypothesis, as this matter will be investigated in the future. Also, the results of this study will be compared with those obtained in the project PN-II-PT-PCCA-73/2012, whose purpose is to assess the residential radon concentrations in 16 counties of Romania.

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