RADON MEASUREMENTS IN VOJVODINA

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INTRODUCTION

Radon, the natural radioactive gas which can be accumulated in indoor air to significant concentrations, gives the great contribution to annual effective dose of population in the world. The internal exposure is caused by the inhalation of radon (^{222}Rn), thoron (^{220}Rn) and their short lived decay products. The most important source of indoor radon is the underlying soil, so the enhanced levels of radon are usually expected in mountain regions where the rocks contain high concentrations of uranium ^{238}U. However, radon levels in plain areas might be also elevated due to soil porosity. The Pannonian Plain, in place of the ancient Pannonian Sea, is a region where such effects should be investigated. The presence of numerous underground hot spring and sources of natural gas, as well as some crude oil reservoirs, point to the possibility of elevated radon levels. In this paper the results of the first indoor radon survey in a South Pannonian Province Vojvodina (Serbia) are presented.

MEASUREMENT METHOD

The main aim of the present study was to determine the maximal annual effective dose due to exposure to radon and to highlight the regions with elevated levels of indoor radon. Based on previous indoor radon measurements, target sampling locations were chosen to be old adobe houses with no concrete construction of the floor. The measurement of indoor radon was performed by Department of Physics in Novi Sad using the etched track detectors CR39 in about 1000 dwellings in all 45 municipalities of Vojvodina. The time of exposure was 90 days during the winter season, from December 2002 to March 2003. The number of detectors per municipality was determined proportional to the number of citizens in the municipality. The detectors were distributed to students of high schools through the cooperation with professors of physics who supervised also the placing and exposure of detectors. The education of students and their relatives and also increasing the public awareness of radon was the advantage of this project. The CR39 films were exposed inside plastic closed containers with such dimensions of micro pores to prevent the entrance of radon progenies (and usually of thoron, ^{220}Rn, as well). The etching, evaluating and counting of tracks were performed by Radosys Company. The measurements were continued during the winter 2003 − 2004 and also 2004 − 2005 in the same manner.

RESULTS

The first radon map was obtained by calculations of the local averages on the basis of administrative boundaries of municipalities and the results were published in [1]. Based on the log-normal distribution of measured radon activity concentrations (Figure 1) the geometric averages were chosen.

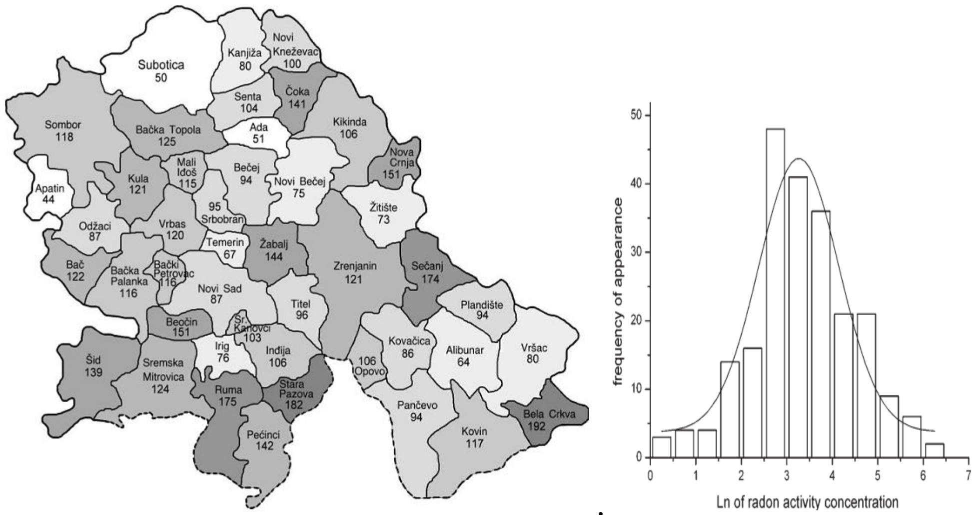

Figure 1. First radon map of Vojvodina with ln-normal distribution of measurements.

About 4 % of the measurements were elevated indoor radon concentrations above 400 Bq/m^3 which is the intervention level in radiation protection legislative in Serbia. According to [2] the mean annual radon concentration could be estimated as:

$$C_0 = 0.73 \times GeoMean \text{ [Bq/m}^3\text{]} \quad (1)$$

where 0.73 is the seasonal correction factor for 3 months duration of the measurement started in December. The effective dose [nSv] can be calculated from the following formula [3]:

$$Dose = C_0 (\varepsilon_0 + \varepsilon_d F) O \quad (2)$$

where C_0 is the mean annual radon activity concentration in Bq/m^3, ε_0 (0.17 nSv/h per Bq/m^3) and ε_d (9 nSv/h per Bq/m^3) are dose conversion factors for radon dissolved in blood following inhalation intake and for inhaled radon, respectively, F is the equilibrium factor between radon and its short-lived progeny (F = 0.4 assumed) [4], and O is the occupational factor (time spent indoors by average European, $O = 0.7 \times 8.76 \times 10^3$ h). Using these relations, with the mean annual radon activity concentration of 76.1 Bq/m^3, an annual effective dose for the whole body of 1.76 mSv/a was estimated which is in good agreement with the WHO value of 2.5 mSv/a [5].

Table 1. Results of the first indoor radon survey of Vojvodina region

survey period	**season**	**number of dwellings**	**measurement time** (days)	A_{SR} [Bq/m^3]	***GeoMean*** [Bq/m^3]	**MAX** [Bq/m^3]
2002/03	winter	968	90	144	104.2±2.3	893
2003/04	winter	941	90	102	68.1±2.6	599
2004/05	winter	926	90	103	73.3±2.3	896

Finally, the influence of house parameters to radon levels was determined concerning the database of 3000 measurements. It was concluded that the construction parameters and life habits of population have dominant influence to radon levels. New buildings with poor isolation concrete floors also have elevated radon levels like the old ones with adobe walls and without floor construction. Geological aspects effect the indoor radon concentration if the houses are single-storied with no basement. Heating modes do not effect too much radon accumulation in rooms, but if the ventilation is poor it may result with significant elevated radon levels.

In Table 2 the statistics of radon potential are showed. According to [2] radon potential is the number of dwellings exceeding a given radon level (200 Bq/m^3) among 1000 dwellings. For these dwellings with elevated radon levels the impact of construction parameters, heating mode, basement and flatness were analysed.

Table 2. The analysis of radon potentials for all radon maps and percentage abundance of house parameters in dwellings exceeding 200 Bq/m^3

	2002/2003	**2003/2004**	**2004/2005**
Radon potential	22 %	13 %	11 %
old house	46 %	45 %	42 %
new house	54 %	55 %	58 %
basement	9 %	8 %	13 %
no-basement	91 %	94 %	87 %
concrete floor	64 %	66 %	71 %
soil / wood	36 %	34 %	29 %
single storied	94 %	99 %	99 %
more-storied	6 %	1 %	1 %
electric heating	35 %	31 %	38 %
solid fuel	38 %	25 %	44 %
gas	21 %	42 %	18 %

CONCLUSION

Recent analyses of epidemiological studies of lung cancer risk from residential exposures demonstrate a statistically significant increase per unit of exposure below average annual concentrations of about 200 Bq/m^3 [6]. Experiences and conclusions of the radon mapping in Vojvodina province of Serbia are discussed in the paper. The benefit of the indoor radon survey of Vojvodina is that the houses with elevated radon levels were found and not expensive reparation were recommended to owners, like plastic isolation, better ventilation etc. The results of repeated measurements confirm the decreasing of indoor radon concentrations to ordinary levels. The future plans are to collaborate in regional and national projects of radon mapping, intercomparisons and common methods of sampling with neighbouring countries, applications to FP7 common radon projects and also to prepare the data for submission to European indoor radon map, using a reference grid with resolution of 10 km × 10 km [7].

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Recent analyses of epidemiological studies of lung cancer risk from residential exposures demonstrate a statistically significant increase per unit of exposure below average annual concentrations of about 200 Bq/m^3. Indoor radon measurements performed in Novi Sad in about 400 houses and flats are presented and discussed in this paper. By measuring gamma-activity of radon daughters, radon activity concentration was determined to be 50 Bq/m^3. In Vojvodina region indoor radon levels were measured by alpha track detectors CR-39 on about 3000 locations during the winter seasons in the period of three years (2003 − 2005). The main aim of the present study was to explore the critical group of population for radon exposure and to estimate maximal annual doses. Existing radon maps which identify regions with elevated radon levels will improve data collection and analysis for the future radon campaigns. Collaboration on the JRC program of European indoor radon map and implementation of grid system are also discussed.