RADON STUDIES IN THE LIVING ENVIRONMENT IN CENTRAL AND EASTERN EUROPE COUNTRIES

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There is a currently growing interest in the effect of exposure to $^{222}$Rn, because it became recognised as an important “pollutant” factor of the environment. Possible lung cancer incidence due to exposure to environmental radon levels may thus account for a fraction or perhaps all the spontaneous incidence.

The paper presents the published results regarding the radon concentrations in indoor air in Croatia, Hungary, Romania, Slovenia, Slovak Republic, Ukraine and Yugoslavia from Carpathian Basin. The study is based on the materials of the International Nuclear Information System (INIS) on a 10 year period (1986 - 1997). It is completed with the results of the papers published in the Conferences volumes, that was not part of INIS. Most of the papers were published in 1992 and 1993 in CEE countries, but they only 2.2 % from world ones.

The number of houses investigated differ from country to country. The main radon source is the soil under the dwellings. The mean values of the radon concentration in this area are among 47 - 800 Bq.m⁻³ in old brick house, among 5-80 Bq.m⁻³ in block of flats. In all countries, maximum values were found in older houses at the level of the basement (420 - 20,000 Bq.m⁻³).

The radon concentration in the tap-water ranged among 0.24 - 3.30 Bq.l⁻¹ (were study in Croatia and Romania). The radon activity concentrations in the natural gas used for heating and cooking are among 88-135 Bq.m⁻³ in Hungary and 693-480 Bq.m⁻³ in Romania.

Carpathian Range of Mountains has a common geological origin and common geophysical and geochemical properties. The obtained results can be compare after the harmonisation of the methods in the CEE countries. The estimation of effective dose due to radon inhalation for a high number of inhabitants will constitute basis for a long debated issue: the effect of low radiation dose.

Keywords: indoor air, radon, diffusion, water, methane gas, exposure assessment

INTRODUCTION

Today the main source of exposure to natural radiation (56%) comes from the inhalation of the radon and its alpha-daughter products. Exposure of the population to radon and its daughters may be increased in future through energy-conserving measures and using the cheaper building materials with high $^{226}$Ra content. There is a currently growing interest in the effect of exposure to $^{222}$Rn. Possible lung cancer incidence due to exposure to environmental radon levels may thus account for a fraction or perhaps all the spontaneous incidence. Occupational exposures to radon have traditionally been monitored in mines. It is established that uranium miners who have long been exposed to high levels of radon in mine environment atmosphere show an increased incidence of lung cancer. Assessment of the risk of developing lung cancer as a result of inhalation of radon daughters is considered to be an important issue in environmental medicine. Diagnosis of health effects due to high indoor radon levels is difficult because many symptoms of IAQ problems are
similar to those of other disorders. There are many pollutant factors that complicate diagnostic efforts.

The natural radioactive noble gas, radon, is formed during the radioactive decay of $^{226}\text{Ra}$ (radium), which is the daughter of $^{238}\text{U}$ (uranium). Radium is present in all environmental factors, such as rocks, soil, building materials and water. Radon can migrate from these and disperses quickly in the open air, but can also accumulate in enclosed areas. The radon concentration in open air depends on radium (uranium) content of the soil, on physical and chemical properties of the soil and on the meteorological conditions. The difference in seasonal variation may be caused by meteorological conditions affecting the exhalation rate from soil.

$^{222}\text{Rn}$ can enter in houses by diffusion from soil and by emanation from building materials, tap water and methane gas. The accumulation of this radionuclide in buildings, depends on several factors such as: the geographical area of the location of the construction, in areas where the underlying ground contains more uranium, the type of building materials, the type and age of dwellings, and the meteorological and seasonal weather parameters. The type of heating used, the living and working conditions, the rate of ventilation and the dimensions of rooms are also important factors for accumulation rate of radon in buildings (Milu, 1992, pp.96-97; Mocsy, 1987, pp.419-424; Planinic, Planinic J. Seasonal variation of atmospheric radon in Osijek. 14th Yugoslav Symp. on Radiation Protection, 8-11 June 1987, Novi Sad, Yugoslavia, 1987, Senitkova 1993, pp.172-177).

The purpose of this paper is to present the published results regarding the radon. The goal of this study is to establish what are the levels of radon concentration in living environment in Central and Eastern Europe countries. The estimation of effective dose due to radon inhalation for a high number of inhabitants will constitute the basis for a long debated issue: the effect of low radiation doses.

**MATERIAL**

The study is based on the materials of the International Nuclear Information System (INIS) on a 10 year's period (1986 - 1997) and completed with the results of the papers published in the Conferences volumes, that was not part of INIS (total 115 papers).

The paper processes the published results regarding the radon concentration in living environment 7 countries of CEE, Croatia, Hungary, Romania, Slovenia, Slovak Republic, Ukraine and Yugoslavia, from Carpathian Basin. There is a temperate zone in Central Europe that has a common geological structure and meteorological conditions; it is the Carpathian Basin. Carpathian Mountains surround approximate 400,000 km$^2$. This has the advantage of showing geographical origin of countries and being allowed for an easy comparison with geologic maps. In this part of Europe exist villages with many family houses built in 15th-17th century. The older buildings have common style used traditional building materials rely on many natural materials from soil and rocks specific for each locality. In the last 30 years in these areas were built many new, multi-storeyed dwellings. Some time used new building materials that originate from industrial processes contain radium in higher amounts. The new block-of flat differ in style, in the building material used, store high and the comfort level.
There is a common characteristic of the zone: the mobility of old population was very low (in rural areas in special) but differ in human activities and economic status of about 40 000 000 inhabitants.

This fact motivates common indoor radon studies in these countries and the other hand the low level of health statues, increasing the lung cancer and respiratory disease in these countries.

RESULTS AND DISCUSSION

General results of the study

Most of the studies on radon concentrations were performed in Hungary and Slovenia (Figure 2.). We mention that many results were published before the start of our study on ten years.

We classified the radon-papers of the themes function in the following four categories: 1. homes, schools and kindergartens, 2. water, 3. general environment (outdoor air, caves, treatment spas with mineral and thermal waters, gas steaming for treatment) and 4. works in which were include inhaled doses. We took into consideration the places where the human being may be exposed to radon. The studies contributions to the knowledge of the radon subject of these groups are represented in Figure 3.

In spite of, the adult people and children spend much of their life within buildings only 30 % from papers report results about the concentration of the indoor radon. Making an analysis of these published results regarding the radon concentration in the dwellings, the following general observations may be drawn:

- the main radon source is the soil under the dwellings (Hakl,1993, pp.184-189; Mocsy, 1996, pp.315-310; Lohobauer, 1997, pp.136-138);
- in all countries, maximum values of radon concentration were found in older houses at the level of the basement. These results were measured in the rooms of the single family detached dwellings without cellar (Mocsy,1996, pp.490-493; Toth,1992, pp.149-152).
- in the houses with several floors, the indoor radon concentrations decreases with the height of the floor (Mocsy,1996, pp.241-244)
- the seasonal variation of the radon concentration indoor presented similar day per night and summer per winter ratios;
- several new building materials (fly ash, phosphogypsum, slag) have been introduced with relatively high $^{226}$Ra concentration; They have an essential contribution on the radon concentration in the rooms (Mocsy, 1993, pp.527-533; Mljac, 1995, pp.299-305; Gheorghe,1997, pp.192-193).

26 % in these studies published results about meteorological conditions in the place were made the measurements. In majority of these results shown the influence of the barometric pressure, rainfall, relative humidity, temperature and wind speed on the radon concentration.

Radon in homes, kindergartens and schools

In order to establish what are the comparable levels of indoor radon concentration in these countries, we selected only the ground floor values of the radon concentration from the authors’
The radon concentrations are among 47 - 800 Bq.m$^{-3}$ in old brick houses and among 5-80 Bq.m$^{-3}$ in new ones. In these countries, radon concentration exceeds in some dwellings the value of 200 - 600 Bq/m$^3$, recommended for action level for dwellings by ICRP 65/93 (ICRP65, 1993). Annual values of the effective dose from radon in the study areas range from 1.2 - 3.9 mSv.y$^{-1}$ (Mocsy,1996, pp.315-320; Mocsy,1987, pp.419-424; Somogyi,1989, pp.177-183; Nikl,1996, pp.225-228; Lohobauer,1996, 136-138;). The results of the radon activity concentration in schools and kindergartens in some localities were presented in Table 2 (Djuric,1991, pp.22-28; Vaupotic,1992, pp.487-493; Planinic,1993, pp.103-111; Vaupotic,1994, pp. 309-314; Planinic,1995, pp.45-41).

A larger sample of indoor radon concentrations in kindergartens was obtained in Ljubljana, that is situated in a quite different geological area. In some cases was evaluated the annual effective dose for the children in the kindergartens under the worst conditions. The obtained value was 10 mSv.y$^{-1}$.

Remediations were applied only in Slovenian kindergarten and some houses in Hungary (Toth,1994, pp.770-774; Planinic,1993, pp.103-111; Vaupotic,1994, pp. 309-314).

222Rn activity concentration in tap water and methane gas

In spite of the main radon source in indoor is the soil, the tap water (use in kitchen and bathroom) and the methane gas (use for cooking and heating) can contribute to the radon activity concentration inside the buildings. The results showed in Table 3. The contribution at indoor radon concentration was significant in zones (Romania) where water comes from the underground 226Ra bearing rock. (Uray,1986, pp.61-66; Kasztovszky,1996, pp.335-347). The increased radon levels have been found in flats when waters rich in radon is running in the bathtub, shower and use for cleaning and dishwashing in kitchen (Mocsy,1996, pp.315-320).

The radon activity concentrations in the methane gas used in houses for heating and cooking are presented in table 4 (Mocsy,1992, pp.231-238, Bohus,1995, pp.11-13; Szabo,1997, pp.231-238).

The experimental results showed that the contribution of natural gas to radon concentration in indoor is about 40 Bq.m$^{-3}$ in cold winter period (the gas was used for heating for 2 x 2 hours every day). These measurements were made in Cluj, Romania (Mocsy,1992, pp.231-238).

222Rn in mineral and thermal waters

Carpathian Basin is very rich in mineral and thermal water with high 222Rn level. Some of these being used therapeutically. The use of mineral and thermal waters during external medical treatment performed in closed spaces (tubs and pools) leads to radon accumulation in the indoor air, especially in the cases of individual treatments, where ventilation conditions are inefficient (Kobal, 1987, pp.257-259; Mocsy,1990, pp.89-95; Lokobauer,1996, pp.373-378; Faj,1996, pp.385-390; Planinic, 1996, pp.227-231) In most cases radon air concentration is highest in individual treatment rooms. The maximum values were obtained Szerbin among 1991 and 1993 in the Rudas-bath, Hungary 4286 Bq.m$^{-3}$ (Szerbin,1994, pp.240-244; Szerbin,1994, pp.319-321).
In mofetes (steams) from Romania were measured $^{222}\text{Rn}$ activity concentration among 2 and 20 kBq.m$^{-3}$ (Szabo, 1992, pp.339-345).

The effective dose estimated for patients (18 days treatment) are among 0.05 - 30 mSv. The staff received 0.8 - 76 mSv/an. Because many people used the balneological treatment in this part of Europe can not neglect this source of exposure.

$^{222}\text{Rn}$ activity concentration in tourist caves

Hungarian, Slovenian and Slovakian tourist karst caves were studied the radon accumulation in different season and meteorological condition. The high levels of $^{222}\text{Rn}$ activity concentration in caves (11 kBq.m$^{-3}$) demonstrate the necessity to extend the radon study in this field. The dose received by the tourist was very low, but the guide was evaluated at the 1-40 mSv.y$^{-1}$ (Somogyi, 1986, pp.227-233; Kobal, 1987, pp.473-479; Kobal, 1988, pp.207-211; Csige, 1991, pp.51; Hakl, 1992, pp.183-186; Jovanovic, 1992, pp.191-192; Hunyadi, 1994, pp.66; Jovanovic, 1996, pp.98-100; Lohobauer, 1996, pp.373-378)

CONCLUSION

After processing the results the following conclusions may be drawn:

1. The survey about indoor radon was started at different periods for CEE countries. The samples were performed at different condition at time, place and season. The number of houses investigated differ from country to country.
2. There are large interval values of the $^{222}\text{Rn}$ activity concentration in living environment, in Carpathian Basin.
3. In all countries the main contributor to the indoor $^{222}\text{Rn}$ content is from the soil, entering directly through the foundation. The presence of cellar will reduce the $^{222}\text{Rn}$ concentration inside houses.
4. The highest values were found in the indoor air during winter, a fact that can be explained by the reduction of rooms’ ventilation. Thus, the highest values of this radionuclides concentration were measured in the detached houses. In some detached houses have presented higher values, than 200-600 Bq/m$^3$ recommended level by ICRP 93, however they cannot be neglected.
5. The $^{222}\text{Rn}$ exhaled by water and methane gas in living condition increased the activity concentration in air of this radionuclides.
6. Essential data about the dwellings were incomplete.
7. These papers describe results used different active and passive methods. The short term $^{222}\text{Rn}$ concentration was determined by alpha measurements in scintillation cells and ionisation chamber. The long term measurements were made with LR-115 and CR-39 Solid Track Detectors and electret. In few cases the concentration of radon was measured by electrostatic deposition of $^{218}\text{Po}$ on a surface barrier detector and alpha spectroscopy. The concentrations of the short-lived radon daughters were determined by air sampling (different flow rates) on a member filter (different pore sizes) and alpha spectroscopy. Some time radon working level instruments were used for measuring progeny activity. Under these circumstances we are not able to compare the values of the measurements without intercomparison. The obtained results can be compare after the harmonisation of the methods in the CEE countries.
8. That the one-site measurement of a room may not yield a representative true value of the radon concentration in the room.
9. There are few data about the radioactivity of the building materials and about the internal doses derived from inhalation. Several factors affect the exposure-dose relation, for example: the fraction of unattached radon daughters, the type of breathing, and rate and depth of respiration, geometrical parameters of different region in the respiratory system and translocation and clearance of the deposited activity. The occupancy and transfer factors used differ to country to country.

10. The Carpathian Basin has many minerals and geothermal water sources used for health resorts. The used of these waters during external treatment performed in normal treatment conditions shown higher values in the cases of individual treatment (tub) and where ventilation conditions are inefficient. The radon concentrations in these spaces depend of the treatment procedures. The values of radon concentrations obtained in several Hungarians and Slovenian caves are in the range from 200 to 6000 Bq.m\(^{-3}\) in Hungarian caves and from 500 to 7500 Bq.m\(^{-3}\) in Slovenian.

11. The radon content in indoor air may be increased in the future by the utilisation of new building materials, energy conserving measures and by the change of living conditions. In the future is possible to increase the indoor exposure of the population. The significance of radon for the human health is well known and thus the measurement of indoor radon is important for the evaluation of its impact in the public health field.

12. Analysing the methods, results and conclusion of these papers the questions raised are:
- which are the comparable values?
- what does “indoor” mean? in which room? at what height from the floor? how are they ventilated? - what kinds of ventilation systems are used? what kinds of heating systems are used?

For establish the dose produced by radon through inhalation we can put following questions:
- what are the transfer coefficients and equilibrium factors were used for dose estimation?
- is the house occupancy factor the same in all countries?

It is necessary an intercomparison performed by the CEE country's laboratory to establish an indication of the precision of measurement, the limit of the detection and the ability to interrelate various measurements. Under these circumstances we are not able to compare the values of the measurements. The estimation of effective dose due to radon inhalation for a high number of inhabitants will constitute the basis for a to long debated issue: the effect of low radiation doses.

REFERENCES
Forgó Cs, Tigru C.M.P. The radon daughters exposure in some Transilvanian houses. Int. Conf. on Indoor Climate of Buildings, 28-30 September 1992, High Tatra, Slovakia, 1992:289-293


ICRP Publication 65. Protection against Radon-222 at home and at work. Ann ICRP 23. 1993, 2


Lohobauer N, Franic Z, Sencar J, Petroci L, Sencar I, Lohner V. Exposure to radon in dwellings below the ground level in the area of Zagreb. IRRPA Symp. on Radiation Protection in Neighbouring Countries of Central Europe, 8-12 September 1997, Prague, Czech Republic, 1997:136-138


Milu C, Gheorghe R. Some influencing parameters of the radon and thoron daughters concentrations in dwellings. Int. Cong. IRPA9, 14-19 April 1996, Vienna, Austria, 1996,2:96-97

Mocsy I, Fulea C, Simon K. The influence of ventilation in rooms upon the effective dose equivalent from inhalation of Rn-222 and their short lived daughters. 4th Int. Conf. Indoor Air ’87, 17-21 August 1987, Berlin(West), Germany, 1987,2:419-424
[23] Mócsy I, Lascu A, Forgó Cs, Motoc A. The effective dose received through inhalation of radon and its decay products by staff in some spas of Romania. 5th Int. Conf. Indoor Air’90, 29 July-3 August 1990, Toronto, Canada, 1990, 3: 89-95


[34] Planinic J, Kobal I, Vaupotic J. Radon concentrations in kindergartens of Osijek and Ljubljana.


[41] Somogyi Gy, Lenart L. Investigation of the radioactivity of the caves in Mountain Bukk, Hungary.


[43] Somogyi Gy, Nikl I, Csige I.Hunyadi I. Radon aktivitas koncentracijanak merese a belegzesbol eredo sugarterheles meghatarozasa hazai lakasok legtereben. Izotoptechnika 1989; 32;4,177-183


### Table 1: $^{222}$Rn concentration in ground floor rooms in some localities in CEE countries

<table>
<thead>
<tr>
<th>Country</th>
<th>Locality</th>
<th>Period</th>
<th>Type of house</th>
<th>$^{222}$Rn activity concentration (Bq.m$^{-3}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Min.</td>
</tr>
<tr>
<td>Croatia</td>
<td>Plomin</td>
<td>1990-91</td>
<td>old brick</td>
<td>55</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1992-94</td>
<td>new brick</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>Sjenjak, Osijek</td>
<td>1989</td>
<td>brick</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Zagreb</td>
<td>1992-94</td>
<td>new brick</td>
<td>19</td>
</tr>
<tr>
<td>Yugoslavia</td>
<td>Belgrade</td>
<td></td>
<td>brick</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Pristina- suburbs</td>
<td></td>
<td>+</td>
<td>43</td>
</tr>
<tr>
<td></td>
<td>Brezovica</td>
<td></td>
<td>concrete</td>
<td>-</td>
</tr>
<tr>
<td>Romania</td>
<td>Mean/Moldova</td>
<td>1990 - 92</td>
<td>detached</td>
<td>21</td>
</tr>
<tr>
<td></td>
<td>Bucharest</td>
<td>1990 - 92</td>
<td>block</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>brick</td>
<td>43</td>
</tr>
<tr>
<td></td>
<td>Targu-Mures</td>
<td>1990 - 94</td>
<td>concrete</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Dej</td>
<td>1994</td>
<td>brick</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>detached</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>Oradea</td>
<td>1986 - 95</td>
<td>brick</td>
<td>27</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>detached</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td>Herculane</td>
<td>1993 - 94</td>
<td>block</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>Cluj-Napoca</td>
<td>1986 - 96</td>
<td>-</td>
<td>13</td>
</tr>
<tr>
<td>Slovakia</td>
<td>Mean/15 loc.</td>
<td>1990 - 91</td>
<td>old brick</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>block</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>Slovenia</td>
<td>1986 - 91</td>
<td>detached</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Ljubleana</td>
<td></td>
<td>-</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>detached</td>
<td>20000</td>
</tr>
<tr>
<td></td>
<td>Zirovski</td>
<td>1995</td>
<td>block</td>
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<td>Ukraine</td>
<td></td>
<td>1992-93</td>
<td>detached</td>
<td>10</td>
</tr>
<tr>
<td>Hungary</td>
<td>Mean/998 loc.</td>
<td>1992-93</td>
<td>detached</td>
<td>2</td>
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<tr>
<td></td>
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<td>1992</td>
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Table 2: $^{222}\text{Rn}$ concentrations in schools and kindergartens in Croatia and Slovenia

<table>
<thead>
<tr>
<th>Country</th>
<th>Locality</th>
<th>Period</th>
<th>$^{222}\text{Rn}$ concentration (Bq.m$^{-3}$)</th>
<th>Min.</th>
<th>Max.</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Croatia</td>
<td>Osijek-school</td>
<td>1990-92</td>
<td></td>
<td>300</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>933*</td>
<td>106</td>
</tr>
<tr>
<td>Slovakia</td>
<td>Mean/ 645 schools and kindergartens</td>
<td>1992-93</td>
<td></td>
<td>645</td>
<td>933*</td>
<td></td>
</tr>
<tr>
<td>Slovenia</td>
<td>Mean/ 730 school and kindergartens</td>
<td>1990-91</td>
<td></td>
<td>14</td>
<td>3504*</td>
<td>448 ± 680</td>
</tr>
<tr>
<td></td>
<td>Osek and Ljubljana</td>
<td>1992</td>
<td></td>
<td>7</td>
<td>3200</td>
<td>390 ± 400</td>
</tr>
<tr>
<td>Yugoslavia</td>
<td>Belgrade</td>
<td></td>
<td></td>
<td>15</td>
<td>148</td>
<td>27</td>
</tr>
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</table>

Note: * these values were representative for monthly (April), respective instantaneous results

Table 3. $^{222}\text{Rn}$ activity concentration in the tap water

<table>
<thead>
<tr>
<th>Country</th>
<th>Locality</th>
<th>Period</th>
<th>$^{222}\text{Rn}$ activity concentration (Bq.l$^{-1}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Croatia</td>
<td>Bizovac</td>
<td>1996</td>
<td>2.7</td>
</tr>
<tr>
<td></td>
<td>Cluj-Napoca</td>
<td>1985-1990</td>
<td>3.30 ; 2.7± 0.8</td>
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<tr>
<td></td>
<td>Turda</td>
<td></td>
<td>1.7</td>
</tr>
<tr>
<td></td>
<td>Sfantu Gheorghe</td>
<td>1975-1985</td>
<td>2.64</td>
</tr>
<tr>
<td></td>
<td>Tusnad</td>
<td></td>
<td>3.50</td>
</tr>
<tr>
<td></td>
<td>Bistrita</td>
<td>1992-1994</td>
<td>8.52</td>
</tr>
<tr>
<td></td>
<td>Miercurea Ciuc</td>
<td>1992-1994</td>
<td>0.24</td>
</tr>
<tr>
<td></td>
<td>Targu Mures</td>
<td>1992-1994</td>
<td>1.5 ± 0.8</td>
</tr>
<tr>
<td></td>
<td>Oradea</td>
<td>1993</td>
<td>2.2 ± 0.8</td>
</tr>
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Table 4: $^{222}\text{Rn}$ activity concentration in methane gas

<table>
<thead>
<tr>
<th>Country</th>
<th>Locality</th>
<th>Period</th>
<th>$^{222}\text{Rn}$ activity concentration (Bq.l$^{-1}$)</th>
</tr>
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<tbody>
<tr>
<td>Hungary</td>
<td>Budapest</td>
<td>1994</td>
<td>88</td>
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<td></td>
<td></td>
<td>135</td>
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<td>Romania</td>
<td>Cluj-Napoca</td>
<td>1991-1992</td>
<td>700</td>
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<td></td>
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<td>940</td>
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<td></td>
<td>Targu-Mures</td>
<td>1961-1981</td>
<td>693</td>
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Figure 1: Comparison of the number of the published papers in world and CEE countries

Figure 2: Number of published papers on „radon” in CEE countries
Figure 3: Distribution of the radon papers in four groups

- Different sites with high radon concentration: 54%
- Homes, schools, kindergartens: 30%
- Water: 8%
- Doses due to radon: 8%