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THE MAP OF INDOOR RADON CONCENTRATIONS IN NORTHEASTERN ROMANIA

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Abstract. The radon concentrations have been measured in detached houses and blocks of flats from cities and villages in Moldavia areas, between 1998 and 2002. The radon activity in detached houses is mainly dependent on the activity of radium in subjacent ground and surrounding soil and the radioactivity of building materials. The map of radon concentration in houses in connection with the map of radium activity in soil shows us a constant ratio between the radon and radium activity. Only 2% among all houses in northeastern territory of Romania exceed the level of 200/Bq/m^3 for radon concentration.
Key words: indoor radon, equivalent equilibrium concentrations, soil radium activity

Rezumat. Au fost măsurate concentraţiile de radon în case şi apartamente din oraşe şi sate în judeţele Moldovei între 1998-2002. Activitatea radonului într-o casă este în principal dependentă de radioactivitatea radiului din solul subiacent şi radioactivitatea materialelor de construcţie. Harta concentraţiilor de radon din case în conexiune cu cea a radiului din sol arată un raport relativ constant. Numai 2% din casele din zona Moldovei depăşesc nivelul de 200 Bq/m^3 pentru concentraţia radonului în interiorul locuinţelor.
Cuvinte cheie: radon interior, concentraţii echivalente de echilibru, activitatea radiului în sol

INTRODUCTION.

The radiation dose from inhaled radon and thoron progeny indoors is the dominant component of population exposure to natural radiation sources accounting for about 60 percent in Romania (1).

The radon concentrations in a building are dependent on the concentration of radium in subjacent ground and surrounding soil, the geological bed rock, the radioactivity of building materials, the ventilation conditions, the meteorological conditions and human activities, also (2). Houses in urban areas differ from those built in rural areas in terms of their structure, the constructional technology applied, architectural features, building materials and heating systems used.

Increased levels of radon progeny are expected to occur in dwellings, because of the activity concentrations in the subjacent ground, surrounding soil and the building materials used.

Previous measurements of indoor radon and thoron progeny indicated higher concentration levels in detached houses (3,7).

Our purpose was to map indoor radon concentrations in connection with the map of radium concentrations in soil.

METHODS

During 1998-2002, indoor radon concentrations have been measured in 520 rooms of detached houses from rural areas and 145 rooms of blocks of flats from six cities.

The radon concentration measurements have been made over all seasons.

Two methods were used to assess the volumetric activity of radon. Firstly, we measured the concentrations of ^{218}Po, ^{214}Pb, ^{214}Br and ^{212}Pb by an active method. A known volume of air sample was drawn (about 0.6 m^3) through an open-faced high efficiency filter paper (98%) at known flow rate (0.01-0.08 m^3/min) for a certain collection time (usually 10 minutes). The deposited activity was measured with a ZnS alpha scintillation counter (30-40% efficiency).

A computer program, very versatile in handling multiple input parameters, have been developed to solve the decay equations for obtaining the activity concentrations of daughters in air, to calculate the equivalent equilibrium concentrations (EEC), the potential alpha energy concentrations and the equilibrium factor F for radon daughters.

The detection limits of our method are in optimum sampling and counting conditions 1 Bq/m^3 for each of ^{218}Po, ^{214}Pb, ^{214}Bi and 0.1 Bq/m^3 for ^{212}Pb (6).

Secondly, during 2001-2002 we measured the radon concentrations directly by a SARAD monitor system. The detection limits were, in optimum sampling and counting conditions, of 2 Bq/m^3.

Three soil samples for every village (280 total samples) have been analyzed for ^{226}Ra activity by gamma spectrometric method in Marinelli beaker geometry, using the Inspector Canberra multichannel analyzer equipped with Na (I) detector.

The detection limit was of 2 Bq/kg in optimum counting conditions (i.e. the counting time 60,000 s and 8% efficiency).

In order to map radon and radium concentrations, data were analyzed by 192 rectangular grids of 15 x 18 km. Total surface was 83,000 km^2 with 5,2 million inhabitants. There were 115 rectangular grids without measurements from mountain areas where the density of inhabitants is very low. Each of them has been assigned to the average values for radon and radium concentrations found in their district.

DISCUSSION

Table 1 presents the average equilibrium equivalent concentrations of radon and radium activity in soil for all counties of Moldavia, as well as their ratio.

Only 2% of all dwellings in Moldavia areas exceed the level of 200 Bq/m^3 for radon concentration the recommended Action Level by NRPB (4).

The EEC average values representative for northeastern for indoor radon is 37±2.5 Bq/m^3 and that of radium-226 activity 36±3 Bq/kg.

The lowest values of radon and radium activity were measured in southern counties (Brăila, Galați: 26 Bq/m^3 and 23 Bq/kg, respectively) and the highest ones in north of Romania (42 Bq/m^3 and 47 Bq/kg, respectively).

Table 1. Average radon concentrations indoors and soil radium activity by counties

County	Soil Ra activity (Bq/kg)	Indoors EEC (Bq/m^3)	Ratio EEC/Ra activity
Brăila	25 ± 3	28 ± 6	1.12
Galați	23 ± 2	26 ± 5	1.13
Vrancea	33 ± 5	38 ± 8	1.15
Vaslui	38 ± 5	35 ± 6	0.92
Bacău	37 ± 15	38 ± 7	1.03
Piatra Neamț	41 ± 9	41 ± 8	1.00
Iași	36 ± 2	39 ± 7	1.08
Suceava	47 ± 12	42 ± 7	0.90
Botoșani	42 ± 12	35 ± 6	0.84
Mean value	36 ± 3	35.7 ± 2.5	1.01 ± 0.04

In other words, there is a good correlation between the level of radon concentration indoor and radium activity in subjacent ground and surrounding soil, as table 1 data shows. This constant ratio (1.01±0.04) could be explained because, in rural area, overwhelming majority of houses was build without concrete basement floor and thus the radon from soil is the main source of indoor levels.

In block flats, the indoor radon have quite same concentration of about 8.7 Bq/m^3 irrespective of their geographical location due to the uniformity of design, building materials and heating system.

The ratio between northern and southern counties for radon and radium activity also goes toward 2.

The results of all measurements show a log normal distribution for ^{222}Rn progeny, as figure 1 illustrates. The average value for equilibrium factor for indoor radon short-lived decay products was 0.15±0.19, ranging from 0.1 to 0.9 (fig. 2).

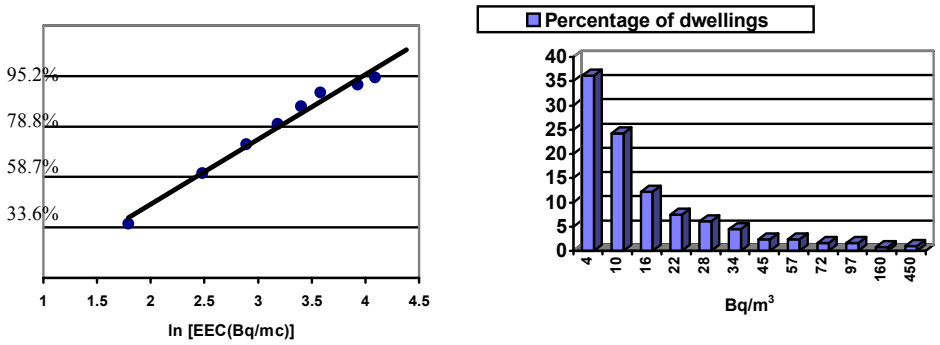

Fig. 1 Distribution of indoor EEC of radon (total sample)

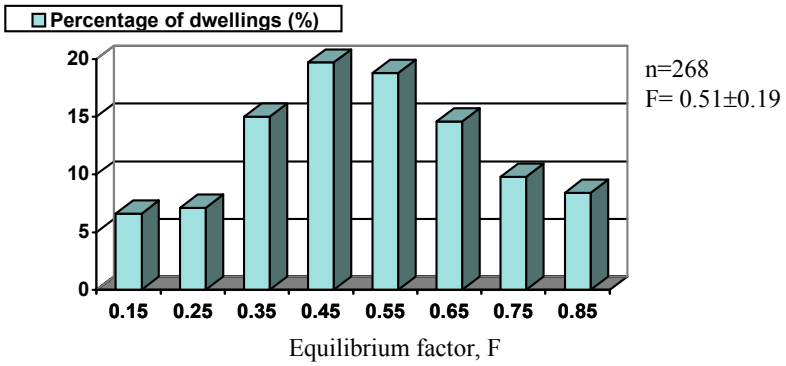

Fig. 2 Distribution of equilibrium factor F for indoor radon daughters

The map of radium activity in soil is illustrated in figure 3 and that for radon concentrations in figure 4, respectively.

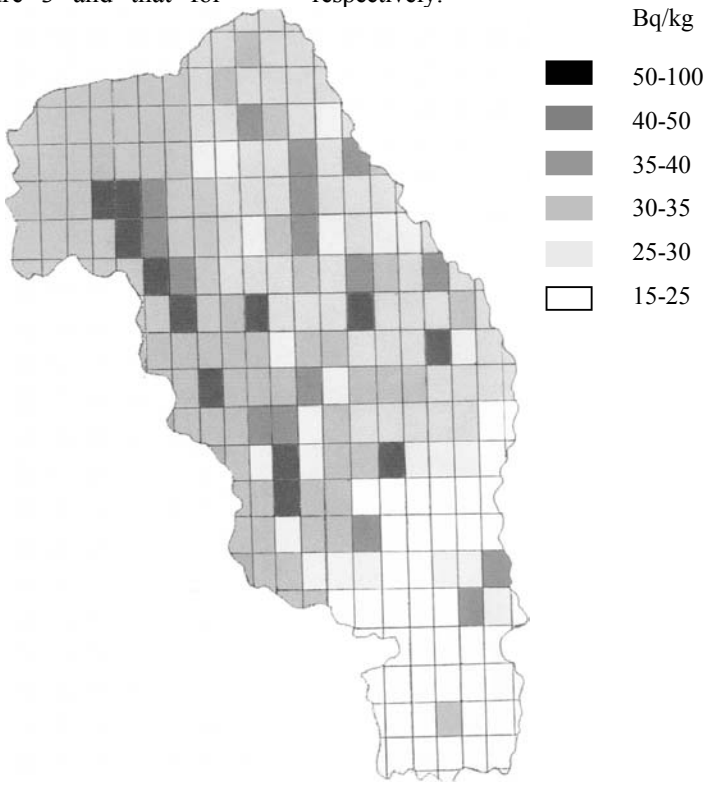

Fig. 3 The map of radium concentrations in soil

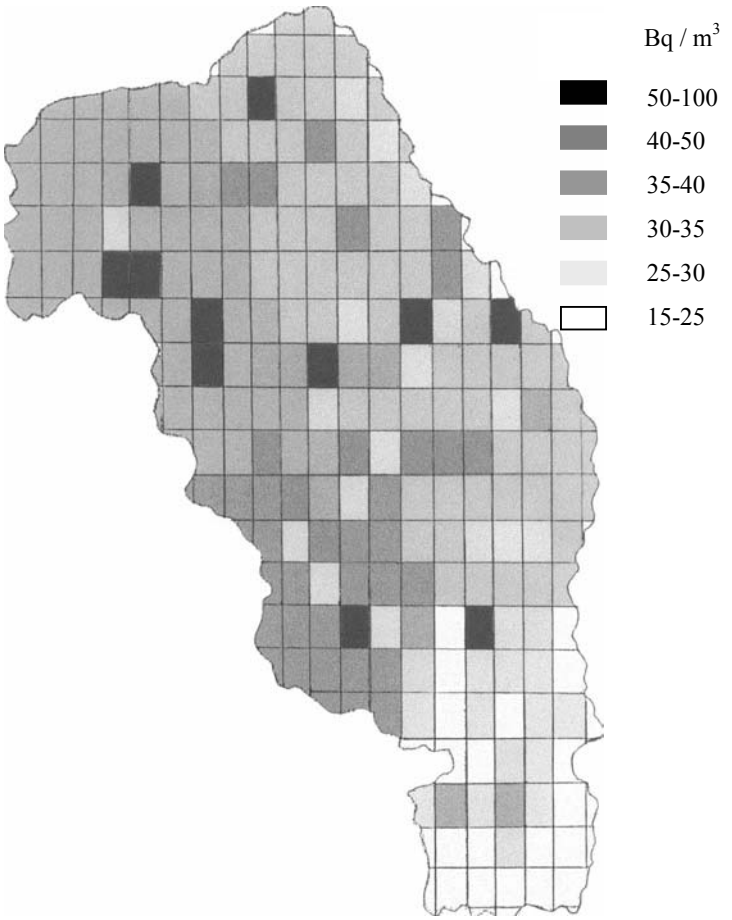

Fig. 4 The map of indoor radon concentrations

CONCLUSIONS

- The mean radon concentrations (EEC) ranged from 26 to 47 Bq/m^3, with a representative value of 36 Bq/m^3.
- The distribution of all measurements shows a log-normal variation for concentrations.
- The ratio of radon concentrations indoor per radium activity in soil is a constant value for all counties of Moldavia (1.01 ± 0.04) kg/m^3.
- Only 2% of all dwellings in Moldavia areas exceed the level of 200 Bq/m^3 for indoor radon concentrations.

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