Radon programme in Czech Republic
Results, Experience and Future

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Abstract.

Radon programme in the Czech republic started in early eighties. Now includes both preventive measures and interventions.

Aim of remedial measures is to promote targeted indoor radon survey in existing buildings and help owners to put into effect reasonable remedial measures. Governmental activities include representative and targeted indoor radon survey, subsidy for remediation measures and test measurements and foster public awareness of radon issue. Indoor radon survey is targeted into radon prone areas delineated with help of geological radon prognosis maps and results of representative indoor radon survey. There are expected some 60-70 000 family houses above intervention level 400 Bq/m^3. There were found 20 000 of them from more than 130 000 totally measured up to now. Building owners can apply for governmental radon mitigation subsidy. Prior to remedial measures radon diagnostics are carried out to objectify radon concentrations, identify radon sources and prepare radon mitigation design. Since survey of long term effectiveness of remedial measures has shown 25 % of them failed after some years, the great importance of long term after mitigation test measurements is evident. Mean effectiveness of remediation was 40 %, best / subsoil suction up 90 %.

Preventive measures are based on control of main potential radon sources (soil gas, building material and supplied water) to avoid building of new houses above recommended indoor radon level 200 Bq/m^3. Radon risk (index) estimation of individual building site bedrock in case of new house siting and building protection according technical building code are obligatory. The estimation of radon-related index of building site is based on standard method including set of radon soil and soil permeability measurements. Beside this, building materials producers are obligated to monitor natural radioactivity in their products. Activity index (including K^{40}, Ra^{226} and Th^{232}) is used as screening level for regulation of potential indoor gamma dose rate, and Ra^{226} mass activity as limit value for limitation of radon exhalation. Similar regulatory system is in practice for public water supplies based on obligatory radon, total alpha and total beta measurements. The survey of preventive measure effectiveness was carried out in the last years. It was shown however, that indoor radon level 200 Bq/m^3 is exceeded in some 20 % of new houses. One of the reasons seems to be unexpectedly low air exchange rate in modern energy-saving houses.

The radon bulletin and special leaflets are periodically prepared to improve public awareness of radon issue. The quantitative survey on radon awareness showed that 75 % of Czech republic residents are aware of this issue.

1. Background

It was clear that uranium rich bedrock of Czech republic territory could be source of high indoor radon concentration. Beside this, several groups of building materials with high Ra^{226} content were discovered in seventies (some hundred buildings in Joachimstahl, nearly 3000 family houses from slag-concrete houses and some thousand buildings from aerated concrete distributed over all territory) that contribute also to elevated indoor radon [1]. The representative indoor radon survey carried out in 2000 flats by solid track detectors in 1992 (long term 1 year measurement) had shown mean value 140 Bq/m^3, that is one of the highest concentration world-wide. It was estimated that radon concentration in some 60-70 000 houses are above 400 Bq/m^3 with extreme up 20 000 Bq/m^3. For that reason radon issues was gradually incorporated into national legislation and governmental decision (Decree 76/1991, Atomic Act No.18/1997, Decree 307/2002, Governmental Decision no. 583/1999 “On Radon Program of the Czech Republic”). The framework of the radon program includes now both interventions and preventive measures.

2. Intervention and remedial measures

Two sets of intervention levels for natural exposure indoors were established:

- guidance levels (indoor radon concentration 400 Bq/m^3 and indoor gamma dose rate 1,0 μSv/h) and
- limit values (indoor radon concentration 4000 Bq/m^3, dose rate 10 μSv/h).

Governmental activities in the intervention programme are:

- to promote indoor radon survey in existing buildings to search out for houses afflicted by high radon concentration,
- to prepare radon risk maps
- to help owners to carry out remedial measures (provide subsidy for radon mitigation)
- carry our test of mitigation effectiveness (by long-term measurements).
- to inform general public on radon issue,

2.1. Indoor radon survey

The first representative indoor radon survey of the country by track detectors was carried out within 1992/3. It was estimated that there are some 2-3% of houses (50-70 000) above intervention level 400 Bq/m^3. The wide-ranging targeted indoor Radon survey was then launched, there were carried out measurements in more than 120 000 family houses and kindergartens up to now, 20 000 of them were found above intervention level 400 Bq/m^3 yet. The nation-wide search for buildings with increased radon content is now a long-term project ensured by SURO in close co-operation with regional and district authorities. Trace detectors are placed in the buildings for the period of one year and then evaluated. The accent is especially on older family houses, school and pre-school facilities in the areas where increased risk of radon penetration from the subsoil is expected. The radon-risk geological prognostic map of the national territory compiled by the Czech Geological Survey (ČGS) in Prague in scale 1:50 000 are used to target radon survey to high risk areas (Fig.1.)

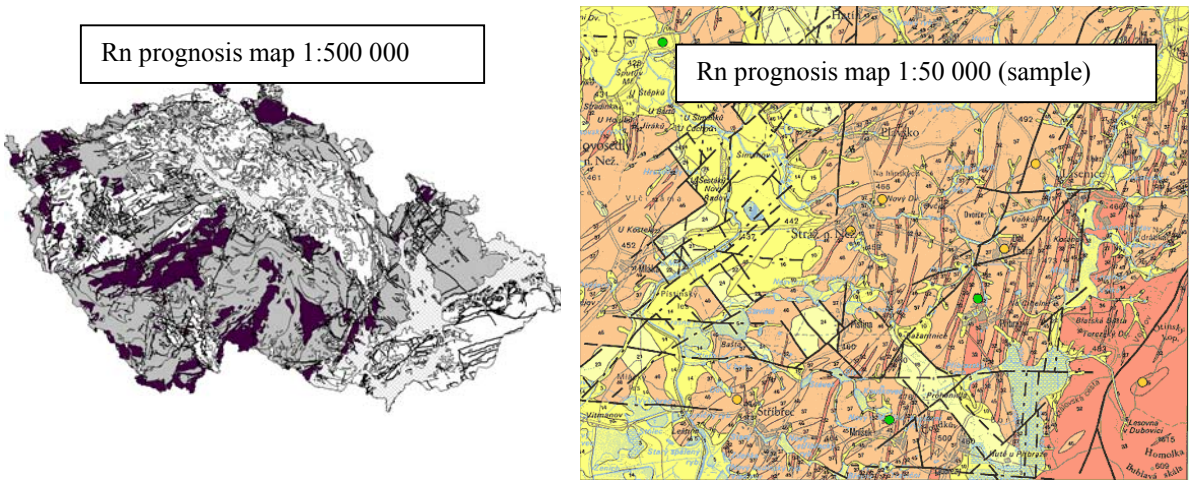

FIG.1 – Radon prognosis maps of Czech republic (scale 1:500 000 and 1:50 000 (sample))

The philosophy of targeted survey is simple: free measurements in all "high radon risk municipalities" and free representative measurements in some 10% house in others municipalities to validate radon prognosis map. The search with focus on the increased-risk areas has been rather efficient, the percentage of identified afflicted buildings being 10 times higher that could be get by random survey, it means 20-30 % of surveyed houses are identified as above intervention level now. SURO is responsible for processing the results of measurements and sending them to the citizens, with booklet of detailed information on measures to be taken. SURO also offers more detailed correspondence measurements prior to remedial measures and after them in the cases where increased values were identified. The map of indoor radon mean values (geometrical means) in all municipalities of the Czech Republic *(FIG.3*) can be easily compared with geological map *(FIG.2).* Even more detailed

comparison of geological prediction and indoor radon data are now under way based on GIS co-ordinates of individual family houses and radon related risk of individual geological structures [6].

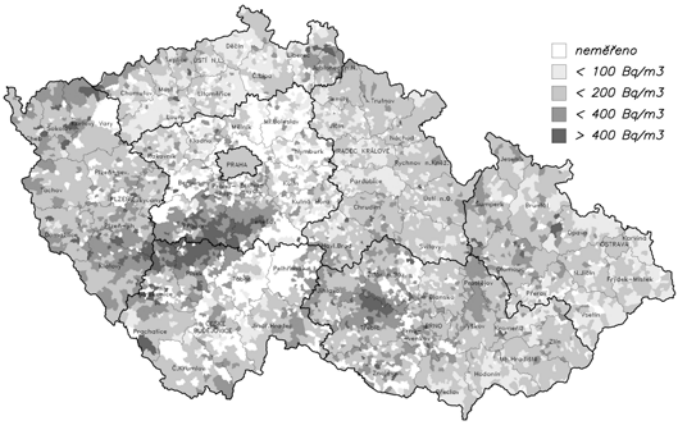

FIG.2: The map of geometrical mean values of the radon volume activity in municipalities of the Czech Republic (for comparison – see geological prediction FIG.1)

2.2. Radon mitigation and governmental subsidy

Anti-radon mitigation has been taken in several thousand Czech family houses and schools with the support of the government since the program was launched. During last 10 years there were realised more than 3500 remedial measures in family houses and more than 300 schools above intervention level (400 Bq/m^3), the owners could apply for grants in range 500 -5000 Euro/mitigation. There were provided obligatory detailed radon diagnostics to identify radon sources and prepare radon mitigation project.

The most frequent remediations were: the new building insulation, sub soil suction, computer controlled pressure ventilation etc. It is clear that test measurements performed after mitigation are very important. They are performed in two steps: 1) short-term (at least one week) measurements by private companies as part of remediation, 2) long term (one year) postal measurements by track detectors provided by government (SURO) to study long term efficiency of remedial measure followed by in-depth diagnostic investigation on site if failure was indicated. A radon expert task group including a court-appointed expert was set up for this purpose and equipped with top-level radon diagnostic equipment, blower-doors technology, a set of continual monitors, a set of pressure sensors for measuring extreme small pressure differentials and air currents etc. However, there have been still number of failures due to the fact that such works are still a relative novelty for the building industry. While short-term measurements had shown mostly successful mitigation, long-term investigation had shown that nearly 25 % remedial measures realised within past ten years had failed. The mean effectiveness is 40%, the best (sub-soil suction) 90%.

The new governmental radon mitigation subsidy is now much more restrictive. It will be provided only if mean indoor radon concentration is above 1000 Bq/m^3, the subsidy is provided subsequently and after approval that mitigation was really successful

3. Preventive measures

Aim of preventive measures is to build new houses with "as low natural radiation as reasonable" and avoid constructing of new houses above guidance levels.
There were accepted guidance levels

- indoor radon 200 Bq/m^3
- indoor gamma dose rate guidance level (0,5 μSv/h).

Indoor radon in new building is regulated by preventive system based on controlling all potential natural radiation sources: radon from soil gas, building material and supplied water.

3.1. Building protection against soil radon

There is obligatory to protect all building against soil radon. According Atomic act: "*Whoever proposes siting of construction with living or accommodation rooms or applies for a construction permit for such a construction, shall ensure the determination of radon-related index of the site and submit the results to the construction office. If such construction is placed on a site with a radon-related index higher than low, the construction shall be protected preventively against radon penetration from the subsoil. The construction office in a decision on the construction siting or in a construction permit shall set down the terms for execution of preventive measures. Determination of radon-related index of a site need not be performed on condition that the construction will have such a location in a terrain that all its structures are separated from the subsoil with an air layer allowing free circulation of air.*" Technical code for protection of new buildings is based on mentioned radon-related index of building site. Since internationally accepted definition of radon-related index and method for its evaluation is not accepted yet, three category (low, medium and high) for radon-related index was defined and used in practice. Evaluation is based on set of radon in soil gas measurement (at least 15 probes in depth 0,8 m necessary), and permeability measurements (classification see table I). New research carried out during 2001-2003 however have changed this attitude and table (10). Radiation protection authority (SUJB) must approve private companies, providing radon-related index measurements.

Table I. Radon-related index of the building site

radon-related index	Radon concentration in soil (kBq/m^3)		
	Low permeability	medium permeability	high permeability
Low	<30	<20	<10
Medium	30-100	20-70	10-30
High	>100	>70	>30

However there exist radon geological prognosis maps of the Czech republic [2] in scale 1:50 000 (FIG.1), it is not allowed to use them for estimation of radon index of individual building site. Evident complex structure of prognosis maps in very detail scale was discovered yet, that is why they are not appropriate for this purpose.

System of radon prevention was launched in 1991 and it is interesting and important to study how it works in practice after 10 years. Preliminary survey of long-term effectiveness of preventive measure was carried out in 2002 including more than 200 new family houses. Radon-related risk of building site performed remedial measures and present indoor radon concentrations were studied. It was discovered that the system does not work as was expected and new houses above indoor radon guidance level are built up to now. There were found mean radon concentration above 200 Bq/m3 in 17 % of the new buildings and in 50 % of family houses there was found at least one room above this level [4]. One of the reasons seems to be unexpectedly low air exchange rate in modern energy-saving houses and still more popular "natural damp cellars without insulation" in the last years. Technical code for radon protection for new building against soil radon is therefore amended. New standard

procedure for testing diffusion characteristic of radon proof membranes was prepared and is used in practice [7]. However it is evident, that research of effectiveness of various "joints", "leakage area", sealing materials ought to be carried out, too.

3.2. System of regulation of natural radioactivity of building materials and in supplied water

According Atomic Act "...manufacturers and importers of building materials, manufacturers and importers of bottled water and suppliers of drinking water for general public shall provide for systematic measurements and evaluation of natural radionuclides concentration, and in the scope specified by an implementing legal regulation shall record and file the results and report them to the SUJB (Radiation Protection Authority). Neither building materials, nor bottled water, with the exception of water designated as a natural healing source, shall be put into circulation, nor drinking water shall be supplied if: 1) the natural radionuclides concentration exceeds maximum permitted levels laid down by an implementing legal regulation, or 2) the natural radionuclides concentration exceeds guidance levels laid down in an implementing legal regulation, with exception of cases when costs of remedial actions aimed at reduction of radionuclides concentration were provably higher than risks of health detriment." All the measurements can be provided only by approved laboratories supervised by SUJB. Supervisors carry out also random sampling and measurements.

3.2.1. Building materials

Regulation of natural radionuclides content in building materials is based on system of exemption levels and limit values. Activity index *I (equation 1),* incorporating mass activities K^{40}, Ra^{226} and Th^{232} (C_K, C_{Ra}, C_{Th}) defined in [3] is used as exemption level for regulation of potential indoor gamma dose rate.

$$I = \frac{C_{Ra}}{300\ Bq\ .kg^{-1}} + \frac{C_{Th}}{200\ Bq\ .kg^{-1}} + \frac{C_K}{3000\ Bq\ .kg^{-1}} \qquad (1)$$

Exemption levels accepted for activity index are different for materials used in bulk amount in the building e.g. bricks, concrete (I=0,5), materials used in smaller amount (I=1,0) and in minor amounts e.g. tiles (I=2,0). Limit values for Ra^{226} mass activity is set for limitation of radon exhalation indoor and differ similarly for building materials used in bulk amount (< 150 Bq/kg) and material used in small amount (< 300 Bq/kg).

3.2.2. Water

Regulation of natural radioactivity in supplied water is based on similar system. Simple screening measurements of radon, total alpha and total beta with exemption levels (Rn^{222} =50 Bq/l, total alpha= 0.2 Bq/l, total beta= 0.5 Bq/l) and obligate first step. Since exemption level is exceeded, in-depth analysis of most important natural radionuclides is obligatory and limitation is bases on effective dose estimation. While the system is compulsory for public water providers, for individual water sources values mentioned above are intended only as guidance level.

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4. Information and public awareness

The radon bulletin and special leaflets are periodically prepared to improve public awareness of radon issue. The radon bulletins are put out twice a year and distributed to all building offices over the country (800 building offices) and to mayors of municipalities in “high radon risk areas”. Special leaflets are prepared to inform on preventive measures and remedial measures.

Two year ago SURO organised a representative sociological survey of the citizen awareness of radon and radioactivity issues [5]. The aim was to find out whether the citizens are sufficiently provided with information enabling them to take informed decisions. A total of 1,100 citizens selected by quota sampling were interviewed in the survey that covered the whole national territory. Among many others, questions were posed as to whether the interviewee ever heard about radon, whether he/she knows how it is measured, what is in his/her opinion the irradiation level from radon in the flats as compared to that from a nuclear power plant under normal operation. It was found that more than 70% respondents had already heard about radon, but only one quarter of all citizens had adequate information about the irradiation levels. Some results of the survey are showed in the *FIG.3*.

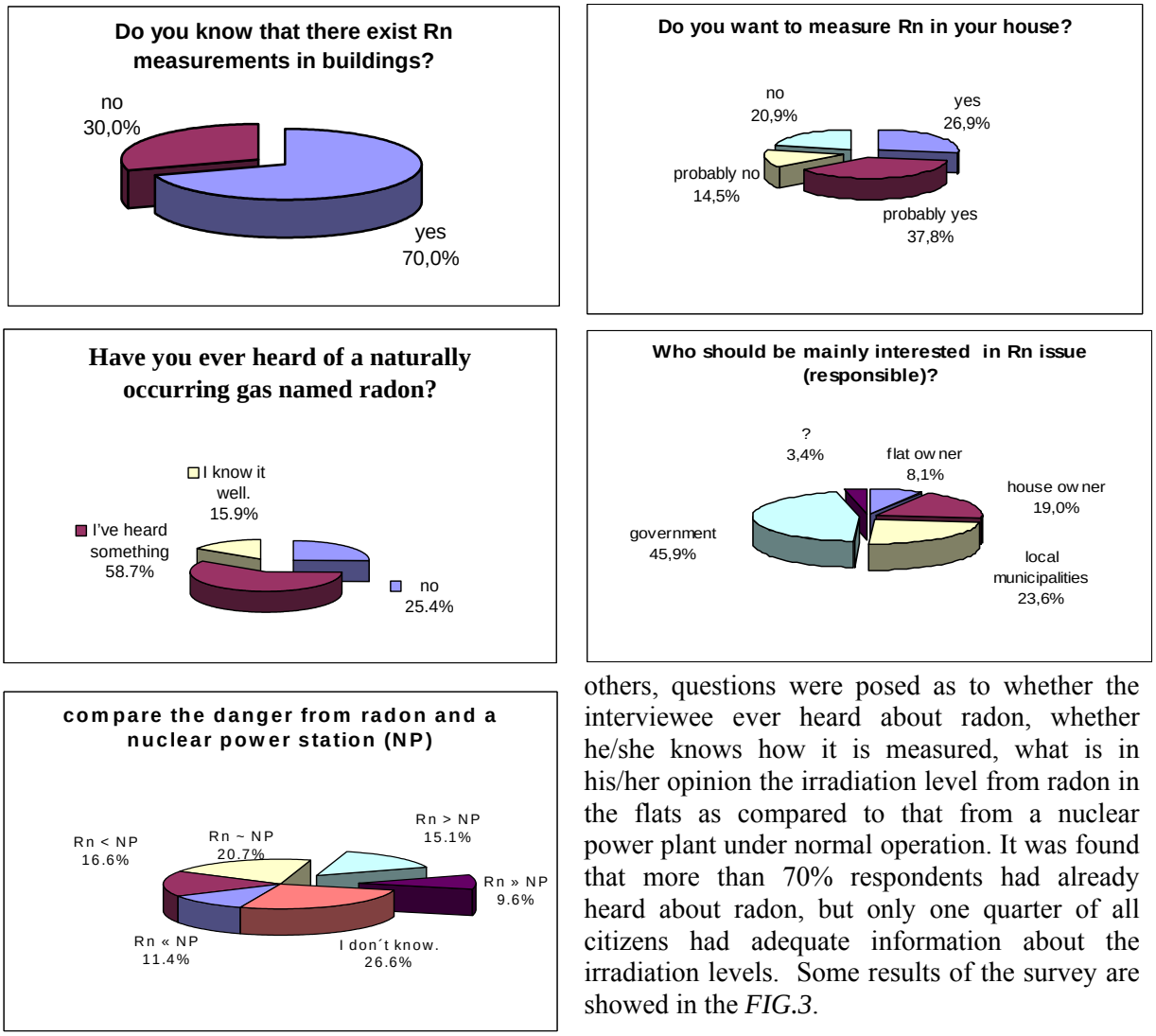

FIG. 3 – Representative sociological survey of citizen awareness of radon and radioactivity issues

5. Topic for further research

During 20 years of duration of radon programme some practical issues have emerged also interesting from scientific point of view those should be investigated in future. Beside others it is e.g.:

- investigation of variability of short and long term measurements and influence of confounding factors (meteorology etc) to objectify interpretation of radon measurements,
- investigation of long-term changes in indoor exposure due to building new energy saving houses,
- development of new radon diagnostic methods to objectify indoor radon concentration, identify and quantify radon sources and radon entry rates, investigate radon permeation through the building construction, to investigate modern methods like blower-door technique, radon entry rate measurements by continuous radon monitors, short and long term ventilation measurements and analysis etc,
- investigation of relation indoor radon vs. soil gas radon, influence of geology parameters and building technology, "indoor- bedrock radon transfer factor" based on probabilistic analysis with aim to get better understanding of geology prediction [9],
- investigation of validity of radon mapping process in-depth [8],
- investigation of new cost/effective remedial measures and long term effectiveness of mitigation measures
- investigation of Rn programme effectiveness

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