EXPERIENCES IN PROTECTION AND REMEDIATION

Martin Neznal, Matej Neznal
RADON v.o.s.Novakovych 6, 180 00 Praha 8, Czech Republic

Abstract

The paper presents an overview of some parts of the Czech Radon Programme - results and experiences resulting from the work of many experts from different institutions (Czech Geological Survey; Charles University of Prague, Faculty of Science; State Office for Nuclear Safety; National Radiation Protection Institute; Czech Technical University, Faculty of Civil Engineering; National Institute for Nuclear, Chemical and Biological Protection; Radon v.o.s. and others). During the last 15 - 20 years. Four main topics are discussed: (i) radon protection of new houses based on an individual approach - a building site characterization; (ii) preventive measures in new houses; (iii) remedial measures in existing buildings; (iv) human factor that may become a weak point of the system in some cases.

Introduction

The first reference to negative health effects of radon appeared in the 16th century: Paracelsus described a specific “miners disease” that occurred in silver mines in Jachymov (Joachimstahl) and Schneeberg, two towns located near the border between Czech Republic and Germany. The symptoms and the development of the disease differed from those of tuberculosis. But as late as in 1951, W.F. Bale (USA) discovered the reason: inhalation of short-term radon decay products (Bale, 1951). The discovery was followed by first epidemiological studies, in the Czech Republic organized by J. Sevc at al. (Sevc, 1993). In 1956, H. Hultquist observed high indoor radon concentrations in Sweden (Hultquist, 1956). Other papers (Akerblom, 1984) described radon from bedrock as a main source of daughter products in dwellings. In the 80s, high indoor radon concentrations were also observed in Czech houses, at first in houses built from materials with higher content of ^{226}Ra (slag concrete; so-called START houses).

The first governmental resolution about radon, as well as the first proposal of the uniform method for radon risk classification of foundation soils appeared in 1990 (Barnet, 1990). The governmental resolution represents the starting point of the Czech Radon Programme.

Radon Protection of New Houses in the Czech Republic - Individual Approach

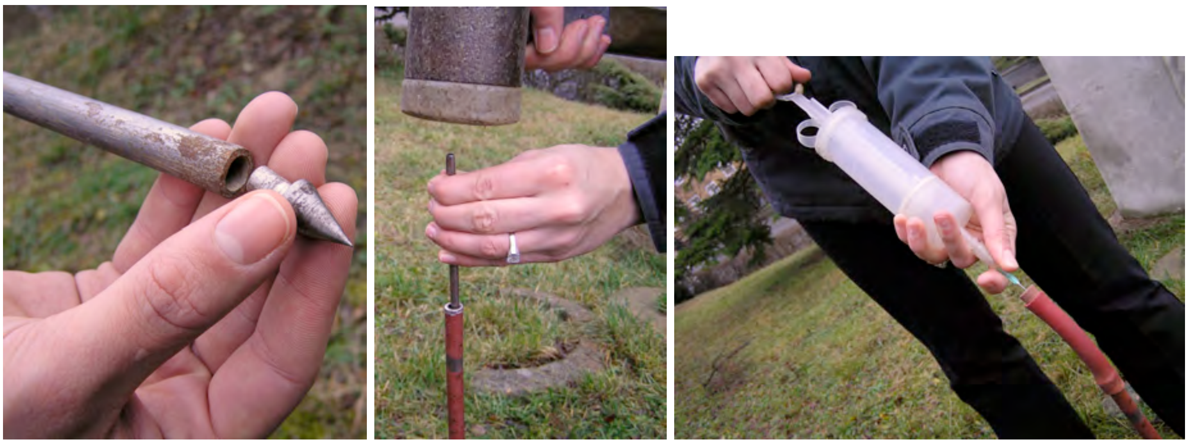
In European countries, a decision making in the pre-construction phase is typically based on radon risk mapping, or on modelling. However, since 1991 in the Czech Republic, the radon potential for prospective building sites has been characterizing by performing in-situ measurements in the soil. Based on these measurements, protective measures are then included in the dwelling design.

The main advantage of the method is given by the fact that it is a site-specific, individual approach. It should enable to propose an optimal preventive strategy corresponding to local conditions. Disadvantages - connected for example with temporal changes of measured parameters - are not critical. In our experience, spatial variations of measured parameters are more important than temporal ones. The soil-gas radon concentrations, as well as soil permeability may vary, often greatly, over a small distance. The occurrence of heterogenities may indicate the presence of faults or tectonic zones or possible kasrst geological formations. Because homogeneous geological structure are rare, any evaluation based on a single measurement would be extermly limited. On the other hand, the occurrence of spatial variations represents a good reason for the protection of a building based on the results of a building site characterization, not on large scale radon risk maps. (Neznal, 1991, Neznal, 1992, Neznal, 1996a, Neznal, 1996b, Neznal, 1996c, Neznal, 1997, Neznal, 2004b).

In accordance with the Czech Atomic Law, results of the building site characterization are used for the design of protective measures. If the radon index is other than low (i.e. medium, or high), the building must be protected against radon. Protective measures are designed and installed in accordance with the Czech National Standard (CSN 730601 Protection of houses against radon from the soil; 1995, 2000, 2006).

The standard method for the determination of the radon index of prospective building sites has been modified (Barnet, 1994, Neznal, 2004a), but the basic principles have remained the same. The evaluation is based on measurement of soil-gas radon concentration and on in situ measurement, or on expert evaluation of soil permeability. Simple, low-cost sampling and measuring techniques are used. A description of the system for soil-gas sample collection follows as an example (See Fig. 1).

The sampling system consists of a small-diameter hollow steel probe with a free, sharpened lower tip. The probe is pounded into the ground to a desired depth below the ground surface using a hammer. A punch wire is then inserted into the probe and the tip is moved a few centimeters lower using a hammer again. This action creates a cavity at the lower end of the probe. A cap containing a rubber stopper and a needle is placed on the open upper end of the probe. The soil-gas is sucked and samples of a controlled volume are collected using a large-volume syringe. To obtain the proper vacuum and to avoid underestimating the soil, gas concenctration, the entire system must be perfectly sealed. More detailed information on sampling and measuring techniques has been published (Barnet, 2008).



(a) (b) (c)

Fig. 1. Soil-gas sampling: (a) Inserting the sharpened tip into the lower end of the probe. (b) The sharp tip is moved a few centimetres lower - this action creates a cavity at the lower end of the probe. (c) Soil-gas sample collection using a syringe.

Currently, apporximately 100 organizations (mostly private firms) are providing radon index services for prospective building sites. Each technician performing these services has to pass a training course and perform a comparison measurement of soil-gas radon concentration at field radon reference sites (Matolin, 1991, Matolin, 2002). A regular metrological verification of all measurement devices for the determination of soil-gas radon concentration is also required. Only firms that fulfil all above mentioned requirements are authorised by the State Office for Nuclear Safety to perform measurement in this field.

Preventive Measures in New Houses - Technical Solutions and Experiences

The Czech National Standard CSN 730601 concerns not only preventive measures in new houses, but also remediation of existing buildings. It also contains principles of designing and application of various types of radon reduction techniques, as well as requirements for radon-proof insulation (Jiranek, 2000, Jiranek, 2001).

Protection of new houses against radon penetration from the ground is based on the use of radon-proof insulation; or in combination with passive, and/or active ventilation systems. The basic principles can be summarized as follows: 1. Only materials with known radon diffusion coefficients can be used. 2. Special attention must be given to jointing and to pipe penetration. 3. The passive ventilation systems must be installed in such a way that they can be easily converted to forced (active) systems. Simple airing of the drainage layer by means of pipes that run from one side of the building to another is not an acceptable solution. The prefered ventilation system consists of several perforated pipes that are connected to one vertical exhaust pipe on which a fan can be installed in the future.

Realization of preventive measures against radon started in the Czech Republic more than 15 years ago. Long-term measurements of indoor radon concentration have shown that the protection has failed in a non-negligible number of houses (Jiranek, 2006) with greater failures occuring in homes built before 1995 (ie. before publication of the first version of CSN 730601). The most important factors responsible for failures are:
- leakages in joints and around pipe penetration,
- partial application - insulation is not applied over the entire surface,
- perforation of insulation during construction works,
- use of insulating materials that were not tested on radon diffusion, or use of low quality products, and
- passive ventilation with inlet and outlet holes in external walls only (without vertical exhaust).

Remedial Measures in Existing Buildings - Technical Solutions and Experiences

Different types of remedial measures in older buildings had been tested in the past (i.ie. ventilation of indoor air with heat recovery, radon-proof membranes, protective coating of the floors, etc.) However, more recently, sub-slab ventilation has shown to be the most effective and appropriate system to solve problems with radon in existing houses (Jiranek, 1998, Jiranek 2002, Jiranek 2004). Soil ventilation systems used in the Czech Republic are usually formed by:
- one, or several perforated tubes drilled beneath existing floors (from the cellar, from an external chase, or from an internal chase),
- one, or several radon sumps installed into the sub-floor region of the building,

- a network of flexible perforated pipes inserted into the drainage layer of coarse gravel placed beneath the floors (reconstruction of floors is necessary in this case),
- a combination of the above stated measures.

The principles of designing and application of various ventilation systems are published in the Czech National Standard CSN 730601. Becasue of its versatility, sub-slab ventilation can be successfully applied in nearly all types of houses. An example concerning a family house with extremely high indoor radon concentrations is described below.

The house is located in Northern part of the Czech Republic, in region of former silver mining. It has a small cellar located under 1/5 of the ground floor area. Two types of floors, i.e. a timber floor and a cracked concrete slab have been found in the ground floor. Very high average indoor radon concentrations (about 20000 $Bq.m^{-3}$ in some habitable rooms; about 70000 $Bq.m^{-3}$ in the cellar) were observed in the house during detailed diagnostic measurements performed in 2004 (See Fig. 2):. The indoor radon concentration in the cellar was the same as the soil-gas radon concentration in the surroundings of the building. In addition, very fast changes of indoor radon concentration were also observed.

In 2005, remedial measures were performed byfirst replacing the timber floors with a concrete slab fitted with a damp proof membrane, thermal insulation, and floor covering A sub-slab ventilation system consisting of two independent sections was then installed. The effectiveness of remedial measures is illustrated in Fig. 3.

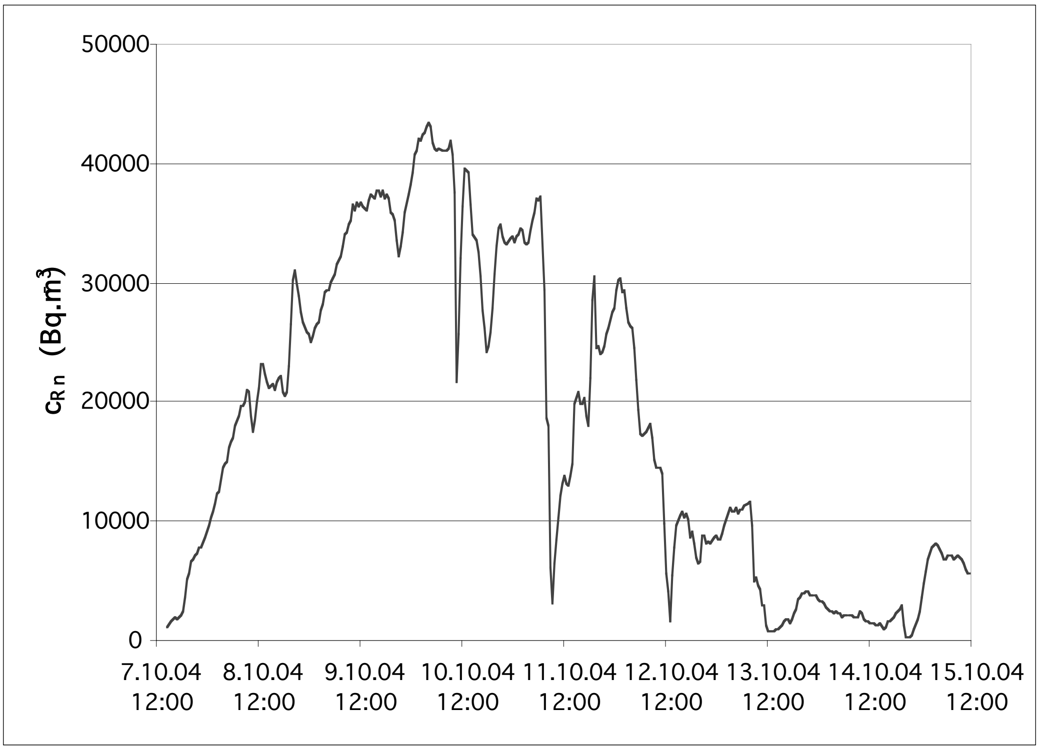


Fig. 2. Continual measurement of indoor radon concentration in the living room - before remediation.

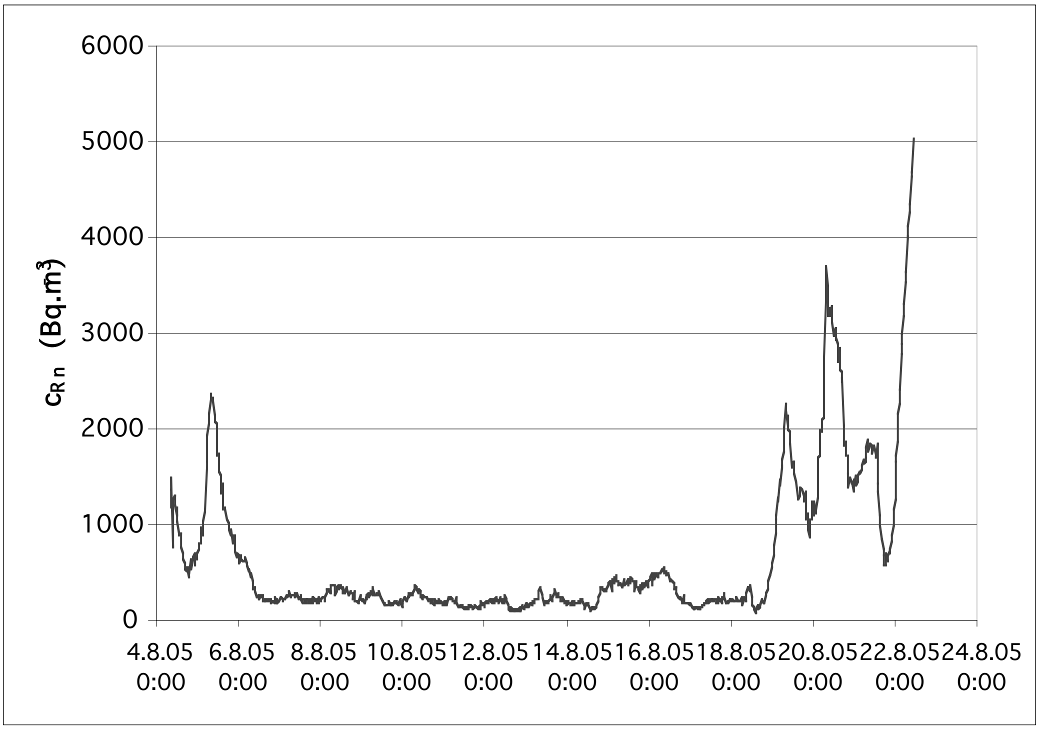


Fig. 3. Continual measurement of indoor radon concentration in the living room - after remediation. Ventilation experiment - 4.8. 8.45 - 11.8. 9.30: gradual start of the 1st section;
11.8. 9.30 - 18.8. 10.15: both sections in operation (maximum power); 18.8. 10.15 - 22.8. 12.00: ventilation switch-off.

The Weakest Link- The Human Factor

The Radon programme in the Czech Republic has a long and rich history.
By using using different remedial measures procedures, we are able to evaluate the risk of radon penetration from the ground, and protect residents of both new and existing buildings from elevated indoor radon levels. These remedial measures and procedures, have been developed, published, field tested and are being applied successfully today.

Although, this approach is sound (if it is performed correctly, the odds of a successful radon remediation is very high). Problems do exist because of simple human error, or misperceptions caused by psychological, or sociological reasons (Neznal, 2008). Two examples follow.

Example A: It is known that the indoor radon concentration significantly changes in time and that it may be strongly influenced by inhabitant's behaviour. Therefore radon measurements using intergrating devices are the most common. Unfortunately, and all too often, these devices are placed and retrieved by untrained nonspecialists. In addition, the residents either knowingly, or unknowingly, too often do things out of malice or ignorance that can have a significant impact on the radon measurement. The following lists the spectrum of human related problems:

- Poor selection of a testing location: The detectors are located in rooms that are declared as habitable rooms (living rooms), but used for other purposes (as storerooms).
- Inappropriate time to test: The testing was being performed during a period of long-term floor reconstruction.

Resident variables such as:

- people want „to avoid any problems“ (increased ventilation),
- people want to get financial support from the government (reduced ventilation),
- people like „experiments“, and
- people want „to safe money“ (and switch-off the sub-slab ventilation system).

Example B: The radon programme is directed by central institutions with the goal to decrease a collective dose. Therefore, a conflict between the individual and an all-society“ points of view is inevitable. However, in some cases remediation may not be recommended. For example, the benefit of the remediation of homes occupied by the elderly may be off set by the stress and discomfort that remedial actions may cause.

Conclusion

A summary of experiences resulting from the Czech Radon Programme has been presented. Disscusion and conclusions relating to partial problems are included in separate scientific papers (See References).

References

Akerblom, G.V.; Anderson, P.; Clavensjo, B. (1984): Soil gas radon - A source for indoor daughters. - Radiation Protection Dosimetry, 7, 1-4, 49-54.

Bale, W.F. (1951): Hazards associated with Radon and Thoron. Memorandum to the files. March 14, 1951. - Health Physics, 38, 1062-1066.

Barnet, I.; Kulajta, V.; Matolín, M.; Veselý, V. (1990): A proposal of the radon risk classification of foundation soils. In: Barnet, I. ed. Radon investigations in CS. Vol. 1. Praha - Geological Survey, 24-28.

Barnet, I. (1994): Radon risk classification for building purposes in the Czech Republic. In: Barnet, I.; Neznal, M., eds. Radon investigations in CR. Vol. 5. Praha - Geological Survey; RADON, corp., 18-24.

Barnet, I.; Pacherova, P.; Neznal M.; Neznal M. (2008): Radon in geological environment - Czech experience. - Czech Geological Survey Special Papers 19, Praha: Geological Survey.

Hultquist, H. (1956): Studies in naturally occuring ionizing radiation. - Kungl. Svenska Vetenskapsakad. Handlingar, 6/3, Almquist and Wiksels, Stockholm.

Jiranek, M.; Neznal, M.; Neznal, M. (1998): Czech experience with sub-slab depressurization systems. In: Barnet, I.; Neznal, M., eds. Radon investigations in CR. Vol. 7. Praha - Geological Survey; RADON, corp., 119-124.

Jiranek, M.; Hulka, J. (2000): Radon diffusion coefficient in radon-proof membranes - determination and applicability for the design of radon barriers. - International Journal on Architectural Science 1 (4), 149-155.

Jiranek, M.; Hulka, J. (2001): Applicability of various insulating materials for radon barriers. - The Science of the Total Environment 272, 79-84.

Jiranek, M. (2002): Efficiency and side effects of sub-slab depressurization systems. In: Barnet, I.; Neznal, M.; Miksova, J., eds. Radon investigations in CR. Vol. 9. Praha - Geological Survey; RADON, corp., 87-94.

Jiranek, M. (2004): Forms of sub-slab depressurization systems used in the Czech Republic. In: Barnet, I.; Neznal, M.; Pacherova, P., eds. Radon investigations in CR. Vol. 10. Praha - Geological Survey; RADON, corp., 119-125.

Jiranek, M. (2006): Consequences of incorrect design and unqualified realization on reliability and effectiveness of radon reduction measures. In: Barnet, I.; Neznal, M.; Pacherova, P., eds. Radon investigations in CR. Vol. 11. Praha - Geological Survey; RADON, corp.; Joint Research Center IES REM Ispra, 123-130.

Matolin, M.; Prokop, P. (1991): Statistical significance of radon determination in soil air. In: Barnet, I., ed. Radon investigations in CS. Vol. 2. Praha - Geological Survey, 20-24.

Matolin, M. (2002): Radon reference sites in the Czech Republic. In: Barnet, I.; Neznal, M., eds. Radon investigations in CR. Vol. 9. Praha - Geological Survey; RADON, corp., 26-33.

Neznal, M.; Neznal, M.; Smarda, J. (1991): Radon infiltration risk from the ground in Chaby, Prague. In: Barnet, I., ed. Radon investigations in CS. Vol. 2. Praha - Geological Survey, 34-39.

Neznal, M.; Neznal, M.; Smarda, J. (1992): Temporal variation of soil gas radon concentration. In: Barnet, I., ed. Radon investigations in CS. Vol. 3. Praha - Geological Survey, 6-12.

Neznal, M.; Neznal, M.; Smarda, J. (1996a): Assessment of radon potential of soils - A five-year experience. - Environment International, 22, Suppl. 1, S819-S828.

Neznal, M.; Neznal, M.; Smarda, J. (1996b): Comparison between large scale radon risk maps and results of detailed radon surveys. In: Barnet, I.; Neznal, M., eds. Radon investigations in CR. Vol. 6. Praha - Geological Survey; RADON, corp., 16-22.

Neznal, M.; Pernicka F. (1996c): Temporal changes of soil-gas radon concentration at a test site - uranium mill taillings. In: Barnet, I.; Neznal, M., eds. Radon investigations in CR. Vol. 6. Praha - Geological Survey; RADON, corp., 79-87.

Neznal, M.; Neznal, M.; Smarda, J. (1997): Intercomparison measurement of soil-gas radon concentration. - Radiation Protection Dosimetry, 72, 139-144.

Neznal M.; Neznal M.; Matolin M.; Barnet I.; Miksova J. (2004a): The New Method for Assessing the Radon Risk of Building Sites. - Czech Geological Survey Special Papers 16, Praha: Geological Survey.

Neznal, M.; Matolín, M.; Just, G.; Turek, K. (2004b): Short-term temporal variations of soil gas radon concentration and comparison of measurement techniques. - Radiation Protection Dosimetry, 108 (1), 55-63.

Neznal, M.; Neznal, M. (2008): Human perception of radon risk and radon mitigation: some remarks. - Radiation Protection Dosimetry; doi: 10.1093/rpd/ncn125.

Sevc, J.; Tomasek, L.; Kunz, E. (1993): A Survey of the Czechoslovak follou-up of lung cancer mortality in uranium miners. - Health Physics, 64, 355-369.