EXPERIENCE WITH THE CZECH APPROACH TO PREVENTIVE MEASURES AGAINST RADON

– ANALYSIS OF FAILURES

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- Czech approach to preventive measures (+ legislation)
- Assessment of failures and malfunctions
  +
  Causation – reasons for higher indoor radon concentrations
- Conclusions

- **Over 50% of the average individual´s radiation dose comes from exposure to radon (radon decay products);**

- **Exposure to radon is the second leading cause of lung cancer (and primary cause of lung cancer for individuals who have never smoked);**

Czech Republic +/- 900 death/year;
United States +/- 21000 death/year.

As for new buildings, we can find various approaches to radon risk and radon prevention as well:

⇨ no regulation in some countries

⇨ if there is a regulation:

⇨ decision making in the pre-construction phase based mainly on radon risk mapping (rarely modelling) the territory is divided into radon-prone and radon-nonprone areas

Radon protection of new houses in the Czech republic - individual approach

But: **The decision whether or not a dwelling needs radon protection can be based on the assessment of radon potential at a given place - on a building site characterization.**

The soil characteristics are measured in-situ and protective measures are designed with respect to the measured properties of the soil and to the dwelling design.

(Czech Rep.; since 1991)

This approach is obligatory.

Czech approach for new buildings

Principles:

- determination of radon potential of a building site (= detailed radon survey) is obligatory with the purpose to classify the building site area from the point of view of the risk of radon penetrating from the soil into the building;
- proposal of optimal preventive strategy corresponds to local conditions (radon index of a building site) and to building type (radon index of a building);
- preventive measures are realized using radon-related construction products; test methods are available;
- design and installation of preventive measures in accordance with the Czech National Standard CSN 73 0601 Protection of buildings against radon from the soil;
- efficiency of preventive measures is controlled.

Legislation – preventive measures

1990 - the first governmental resolution about radon (No. 150, May 1990)
the first proposal of the uniform method for radon risk classification of foundation soils

1991- acceptance of the Decree of the Ministry of Health of the C.R. on the requirements for limiting radiation exposure due to radon and other natural radionuclides (No. 76/1991)
action level 200 Bq/m3 (EEC) for existing houses
guidance level 100 Bq/m3 (EEC) for new buildings
preventive investigation levels, 226Ra in building materials and 222Rn in supplied water

1994 - modification of the origin proposal of the classification method for radon risk classification of foundation soils

1995 - competency in the field of radiation protection transferred from the Ministry of Health to the State Office for Nuclear Safety (the Law No. 85/1995)
Czech National Standard CSN 73 0601 Protection of houses against radon from the soil

1997 - Atomic Law (No. 18/1997) - regulation and control of all possible radon sources
Decree of the State Office for Nuclear Safety No. 184/1997 on requirements of radiation protection

1998 - modification of methods for indoor measurements and radon diagnostic

1999 - governmental resolution about radon programme (No. 538, May 1999)

2002 - modification of the Atomic Law (No.13/2002)
new Decree of the State Office for Nuclear Safety No. 307/2002 on radiation protection
action level 400 Bq/m3 (radon concentration in air) for existing houses
guidance level 200 Bq/m3 (radon concentration in air) for new buildings
guidance level 1000 Bq/m3 (radon concentration in air) for workplaces
proposal of modification of the uniform method for radon risk classification of foundation soils

2004 - new uniform method for radon risk classification of foundation soils

2005 - modification of the Decree of the State Office for Nuclear Safety on radiation protection (No. 499/2005) investigation level 400 Bq/m3 (radon concentration in air) for workplaces

2006 - last modification of the Czech National Standard CSN 73 0601 Protection of houses against radon from the soil

2009 - new governmental resolution about radon programme (No. 594, May 2009) and the Action plan for the period 2010 - 2019

The basic formula from the legislation: „If the radon index is other than low (i.e. medium, or high), the building must be protected against radon.“

RP „Assessment of failures and malfunctions in the system of protective measures against radon at chosen buildings“

Chosen 15 family houses - various
- ✓**geological conditions,**
- ✓**construction type,**
- ✓**preventive measures (if applied).**

- ➢**Study of available documentation.**
- ➢**Visual inspection (building materials and their origin, spatial arrangement, quality of different parts of the construction, mainly at the contact between the sub-soil and the building, thickness of windows and doors, visible cracks and leakages).**
- ➢**Diagnostic methods – to identify and quantify the radon sources (repeated determination of radon index, air sampling from selected locations suspected as potential radon entry pathways, analysis of radon entry pathways and indoor radon transport and distribution).**

Observed reasons for higher indoor radon concentration

1st group – 8 cases

- the legislation rules for protection against radon were not followed at all in these buildings. The assessment of radon risk of the building site, obligatory for each new building, was not performed, although it represents the necessary starting point
- appropriate preventive measures could not be then chosen and designed (the real radon index was underestimated)
- the failure was connected with various errors during construction (insufficient joints of membranes etc.).

Neither the owner, not the responsible authority, required the control of efficiency of preventive measures by means of indoor radon concentration measurements immediately after completing the new house – the elevated indoor radon values were usually detected several years after construction.

Example A:

new family house with a small cellar, located in the region known for really high and extreme soil gas radon values

But:

- nobody followed the legislation rules for protection against radon;
- radon index assessment was not performed;
- the preventive measures could not be designed sufficiently (they corresponded to the medium radon index: radon-proof membrane – plastic membrane with dimples);
- the control of efficiency was not required and performed.

Average indoor radon values (7 years after construction):

cellar 575 Bq.m^{-3}
bedroom 1824 Bq.m^{-3}
kitchen 520 Bq.m^{-3}

Study of available documentation
Visual inspection
Diagnostic measurements

Radon index of the building site:

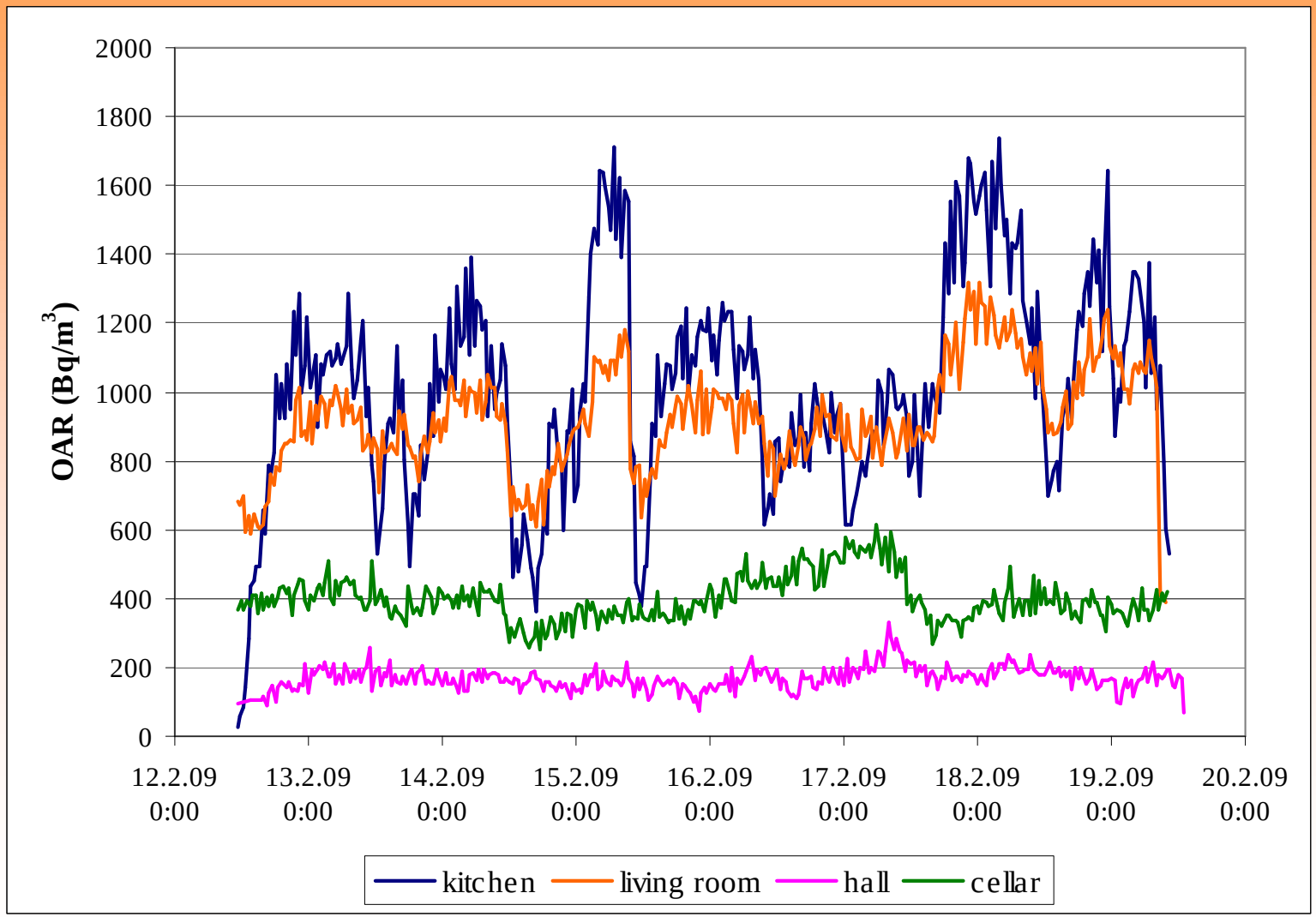
c_A = 114,3 – 390 kBq.m^{-3}
c_{A75} = 236,9 kBq.m^{-3} **> high radon index**
high permeability

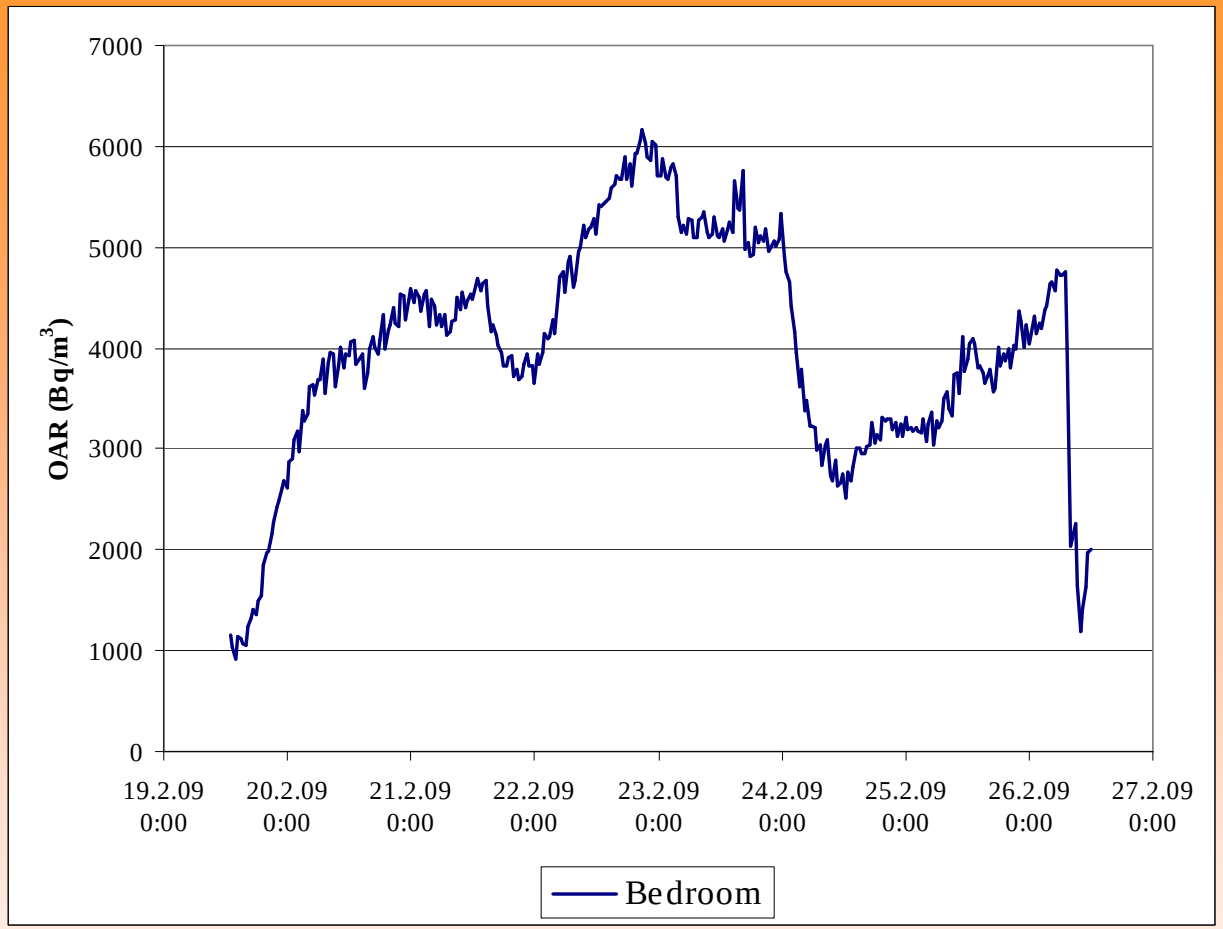
Potential radon entry pathways:

radon concentration in the samples of air taken from chosen leakages (at the contact between walls and floors in both bedrooms) varied from 2,4 kBq.m^{-3} to 7,8 kBq.m^{-3}

Simultaneous one week continual measurements in different parts of the house

-the indoor radon dynamic study





Average values:

Room – floor	[Bq.m^{-3}]
Bedroom – ground floor	4010
Kitchen – ground floor	1011
Living room – ground floor	924
Hall - ground floor	169
Cellar	399

Reasons for higher indoor radon concentrations:

- radon index assessment was not performed;

- the preventive measures were designed insufficiently, because they corresponded to the medium radon index (radon-proof membrane without any subslab ventilation or another combination due to the Czech National Standard);

- imperfections occurred during the construction; some joints of the membrane were not sealed perfectly and the membrane was probably also punctured during the construction of the floor.

Note: the elevated indoor radon values were detected several years after the construction

2nd group – 3 cases

- although the radon index of the building site was determined, the architect/designer did not respect the Czech National Standard, the preventive measures were designed in a wrong way, again in connection with some failures during construction;

- because the owners were familiar with radon awareness, they asked immediately after completing the house to control the quality and efficiency of preventive measures;

- the higher indoor radon values were detected very soon and the owners asked immediately for the remediation.

Note: the remediation was paid in all cases by the building contractor and/or designer).

Example B: new single-family house, without cellar

Although the high radon index of the building site was specified during the detailed radon survey, only the radon-proof membrane from bitumen with Al foil was proposed and designed as the basic preventive measure against radon from the soil.

This choice did not respect the Czech National Standard, because bitumen membranes with Al foil cannot serve as (the only one) radon proof membrane due to their very low tear resistance.

Moreover, the joints of the membrane were not perfectly sealed.

During control measurements in a newly built house, the indoor radon concentrations varied from about 500 to more than 1000 $Bq.m^{-3}$.

As the higher indoor radon values were detected very soon, the owner agreed with the building contractor/designer on the remediation, performed by a professional firm.

For remediation, the most effective solution based on the installation of a sub-slab depressurization was chosen and realized. The soil gas was sucked from perforated tubes drilled into the sub-floor layer from the external trench excavated in the ground along a part of the house.

The effectiveness of the additionally applied measures was significantly better compared with the effectiveness achieved by the original measures.

Ventilation experiment

(9.10. 15,45 – 22.10. 17,10)	Indoor radon concentration ($Bq.m^{-3}$)
room „2“	237
living room (+ hall + kitchen)	266
study room	185
room „1“	182

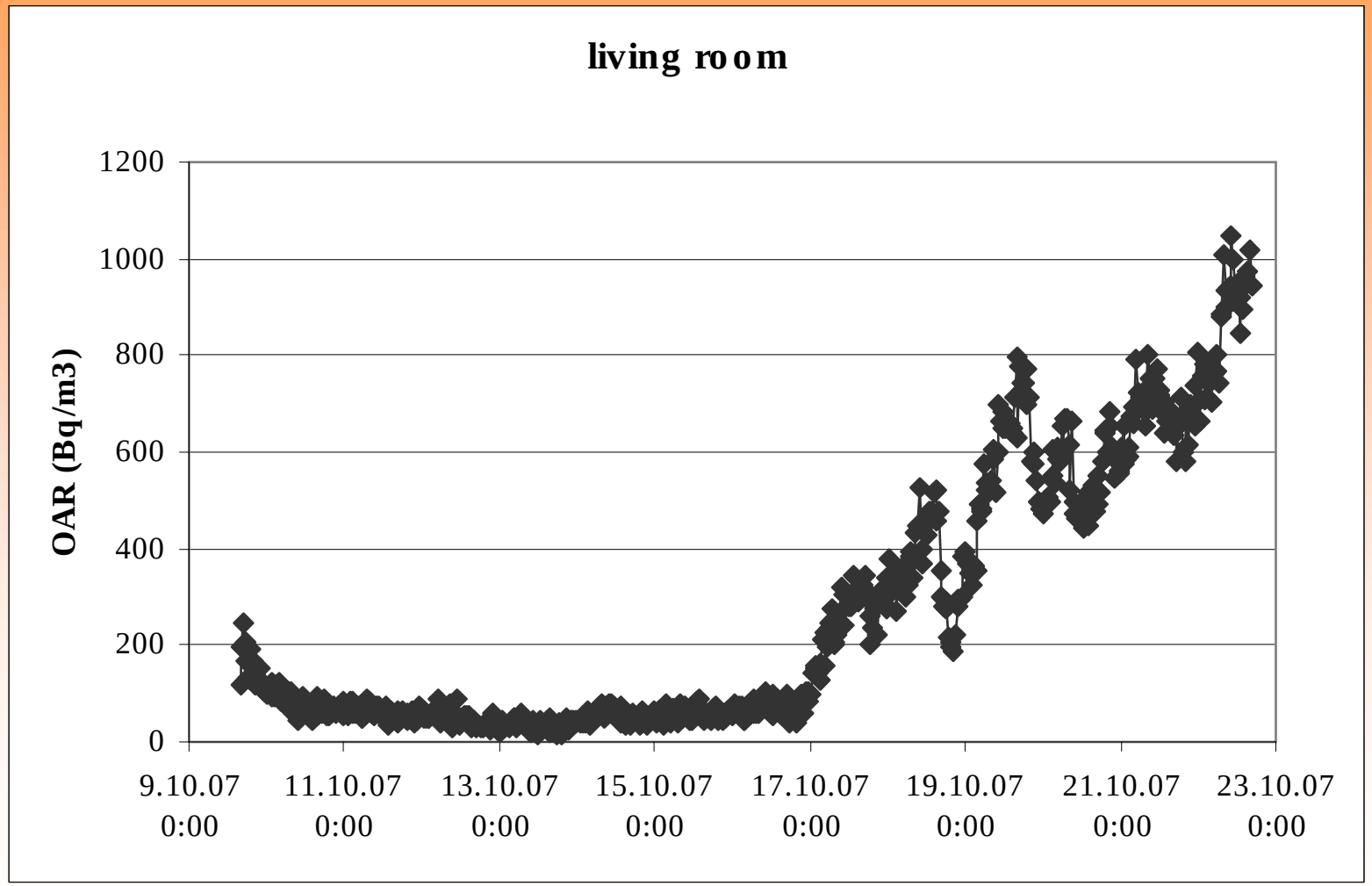
Active ventilation in operation

(9.10. 16,15 – 16.10. 18,30)	
room „2“	62
living room (+ hall + kitchen)	62
study room	72
room „1“	97

Ventilation switch-off

(16.10. 18,30 – 22.10. 17,10)	
room „2“	460
living room (+ hall + kitchen)	512
study room	322
room „1“	285

Ventilation experiment – simultaneous continual measurements of radon concentration in different parts – living room



3rd group – 2 cases

- legislation rules were fully followed, i.e. the radon index of the building site was determined, the preventive measures were chosen and designed with respect to the Czech National Standard;

- but the fatal error(s) during construction caused the communication between the subsoil and the indoor environment and the elevated indoor radon values.

Note: although the owners were familiar with radon awareness, they did not asked immediately after completing the house to control the quality and efficiency of preventive measures; the responsible authority did not require the indoor radon concentration measurements as well.

Example C:

new family house without cellar

Due to the medium radon index of the building site specified during the detailed radon survey, the radon-proof membrane from high density polyethylene was proposed and designed as the basic preventive measure against radon from the soil.

Unfortunately the authority responsible for the building permission, as well as the owners of the house did not require the control of the efficiency of those preventive measures by means of indoor radon concentration measurements.

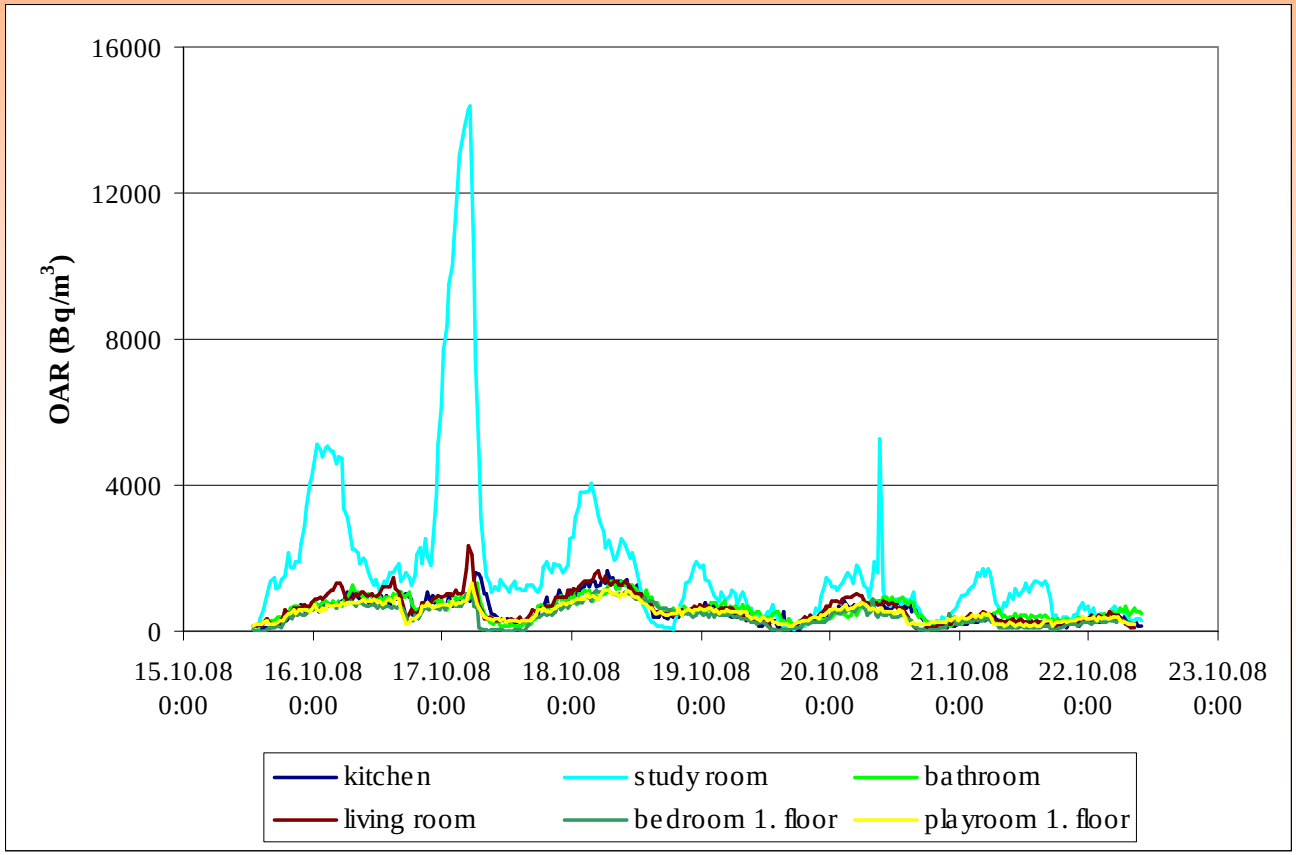
After ten years, the owners happened to read the offer of the National Radiation Protection Institute for free of charge indoor radon measurements in new houses.

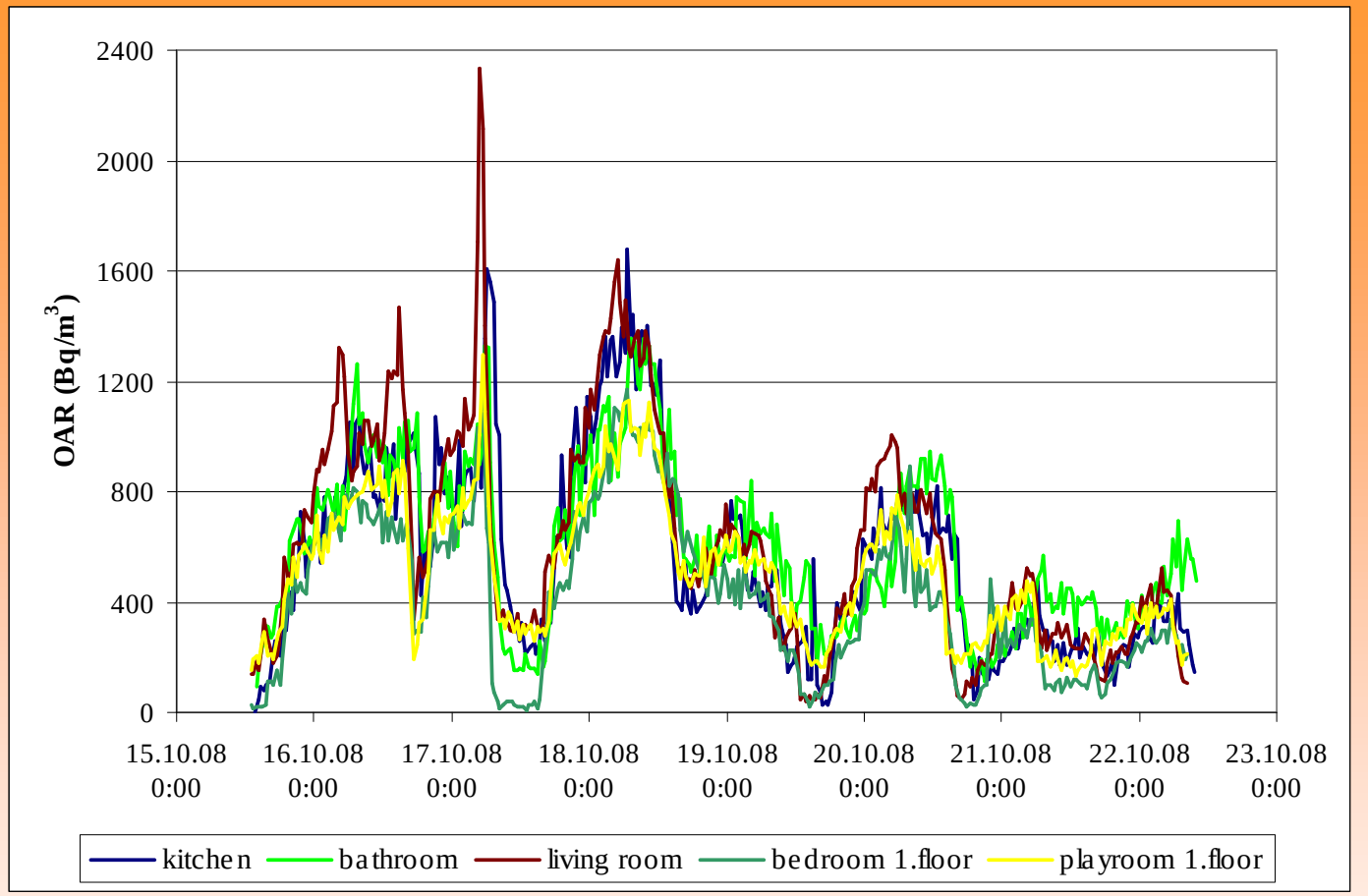
The results from the first indoor radon measurements (long term integral measurements, one year exposure period, track etch detectors RAMARN) were not pleasant:
kitchen (ground floor) 946 Bq.m^{-3}
bedroom (first floor) 663 Bq.m^{-3}

During the visual inspection of the building (mainly of the construction at the contact between the sub-soil and the building and of visible cracks and leakages) we have found an uninsulated non-sealed inspection chamber under the trap door in the study room under the linoleum. The radon proof membrane was not jointed, probably the responsible person forgot to do it and nobody did not recall that detail.

When we sampled the air from the chamber, we received following results: 55,5 kBq.m^{-3} (sample just under the trap door); 84,5 kBq.m^{-3} (sample at the bottom of the chamber); 46,6 kBq.m^{-3} (sample under the edge of the membrane).

The main radon source was identified. Air sampling from selected locations (mainly leakages between the walls and floors) verified the radon pathways above the membrane from the chamber as well, but the main source is the air coming from the uninsulated chamber through the trap-door directly into the study room and subsequently to other rooms. Simultaneous continual radon monitoring confirmed those expectations.





Average values:		[Bq.m^{-3}]
Study room – ground floor		1795
Kitchen – ground floor	559	
Living room – ground floor		613
Bathroom – ground floor		610
Bedroom – first floor		419
Playroom – first floor		507

4th group – 2 cases

- legislation rules were not fully followed, although the performed radon survey specified the radon index of the building site and the preventive measures were chosen and designed with respect to the Czech National Standard;
- we have found higher radon index of the building site in comparison to the originally determined one, so the prevention against radon could be underestimated;
- these inadequate measures, in connection with problems at joints of the membrane or with a fatal error during construction of the house caused the elevated indoor radon values.

Example D:
new family house
without a cellar

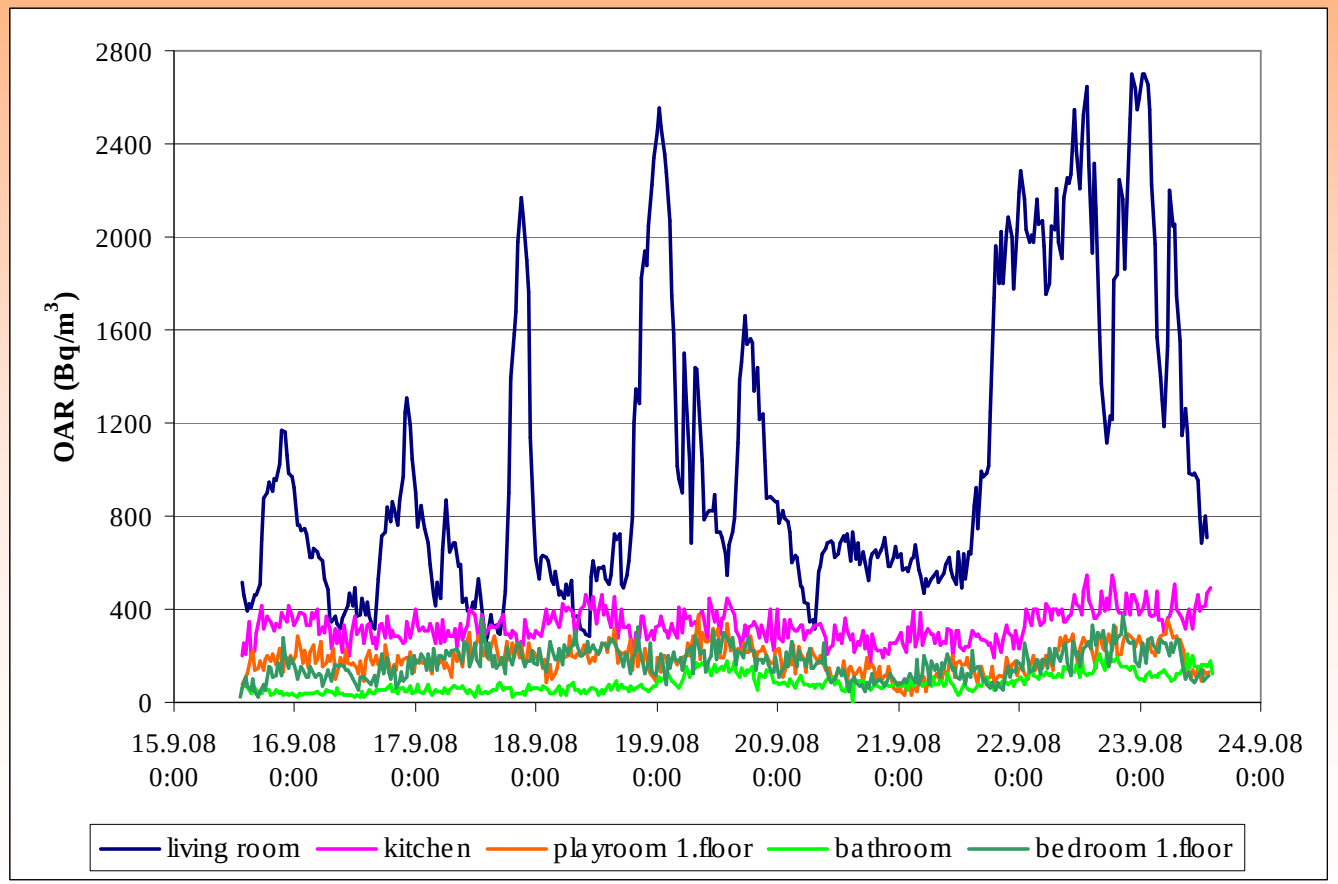
- **Although the radon survey specified the low radon index, the preventive measures were proposed and designed like for the medium radon index.**

Note: the underestimation of the radon risk was caused probably by errors during sampling of the soil gas from really low permeable environment (although the perfect sealing of all parts of the equipment is required).

- **The choice of the radon proof membrane - bitumen membrane with Al foil - did not respect the Czech National Standard, because bitumen membranes with Al foil cannot serve as (the only one) radon proof membrane due to their very low tear resistance.**

Moreover, the joints of the membrane were not perfectly sealed (radon concentration in the samples of air taken from chosen leakages at the contact between walls and floors in the living room) .

Average values:	[Bq.m^{-3}]
Living room – ground floor	1032
Kitchen – ground flor	328
Bathroom – ground floor	83
Bedroom – first floor	169
Playroom – first floor	186



CONCLUSIONS

⇨Almost 20 years experience with preventive measures confirms the effectiveness of the Czech radon programme. The results of control indoor radon concentration measurements in newly built houses are mostly satisfactory. Only in some rare cases, the efficiency of the preventive measures is lower than expected, or the whole system fails due to various reasons.

⇨ As can be seen from all observed examples, facts responsible for failures could be clarified. In general, the unsatisfactory results were caused by the fact, that the legislation rules for protection against radon had not been followed at all, or the specific error occurred during the radon survey, design of preventive measures and/or construction (the lack of knowledge and experiences).

CONCLUSIONS

We should not forget, that the education and publicity campaigns, as well as the public awarness on radon issue, are important parts of the programme.

Because our goal is not (only) to fulfill the legislation rules,

but mainly to MINIMIZE
the (radon) risk at all.

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Thank you