RADON MEASUREMENT IN WORKPLACES – EXPERIENCE AND STRATEGIES

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Legal Framework and workplaces classification

Implementation

- **Council Directive 2013/51/Euratom** of 22 October 2013 laying down requirements for the protection of the health of the general public with regard to radioactive substances in water intended for human consumption.
- **Council Directive 2013/59/Euratom** of 5 December 2013 laying down basic safety standards for protection against the dangers arising from exposure to ionising radiation

Act No. 263/2016 of Coll. Atomic Act; Implementing Decree No. 422/2016 of Coll. on Radiation Protection and Security of a Radioactive Source)

Workplaces categories in accordance with legislation

- **Planned exposure situations in a workplace with potentially increased exposure to a natural source of radiation**

1) Workplace with potentially increased exposure to a natural source of radiation

a) on the board of an aircraft flying at an altitude of over 8 km,

b) workplaces using a material with increased content of natural radionuclides (exhaustive list specified)

2) Workplaces with increased exposure to a natural source of radiation

exposures of a worker in a workplace with potentially increased exposure to a natural source of radiation exceeding the **effective dose of 6 mSv per year** after implementation of radiation protection optimization

- **Existing exposure situation - workplace with potentially increased exposure to radon**

1) **Underground workplace**
2) **Workplace in which water from an underground source is pumped, collected or otherwise similarly handled, in particular pumping stations, spa facilities, bottling facilities, water treatment facilities or water towers,**
3) Workplace located on an underground or first ground floor of a building which meets the conditions laid down in implementing legislation

Legal Framework and workplaces classification

Workplaces handling material with increased natural radionuclide content (exhaustive list specified)

a) extraction, transport by pipelines or processing of crude oil and gas,
b) coal extraction,
c) ore extraction,
d) processing of niobium or tantalum ore,
e) processing of raw materials containing rare earth elements,
f) primary iron output,
g) smelting of tin, lead or copper,
h) production of cement, including maintenance of clinker furnaces,
i) production of phosphate fertilisers, production of phosphoric acid or thermal production of phosphorus,
j) **production of a titanium-dioxide-based pigment**,
k) processing of zircon or zirconium,
l) production, processing or use of materials containing thorium and uranium,
m) **combustion of coal in an installation with thermal output exceeding 5 MW, including the maintenance of boilers**,
n) generation of geothermal energy,
o) operation of a treatment plant to treat underground water or sludge resulting from a source of underground water,
p) treatment of material in which it was discovered that its natural radionuclide content exceeds the clearance level or increases the spatial dose equivalent rate by more than 0.5 μSv/h,
q) mining activity,
r) mining activity performed underground, or
s) activity relating to mining waste treatment.

300 Bq/m3 for the radon average activity volume concentration in the air during work performance and

1 mSv per year for the effective dose, which does not include doses received from exposure to natural background radiation or from exposure to radon and its progeny, have been exceeded.

If levels are exceeded - individual doses of workers are to be assessed based on repeated measurement and duration of stay in the workplace - possibility of exceeding **effective dose of 6 mSv per year** or **one third of the limits defined per calendar year** pursuant the legal provisions

Legal Framework and workplaces classification

Workplace that may be subject to increased exposure to radon
Conditions for classifying workplaces:

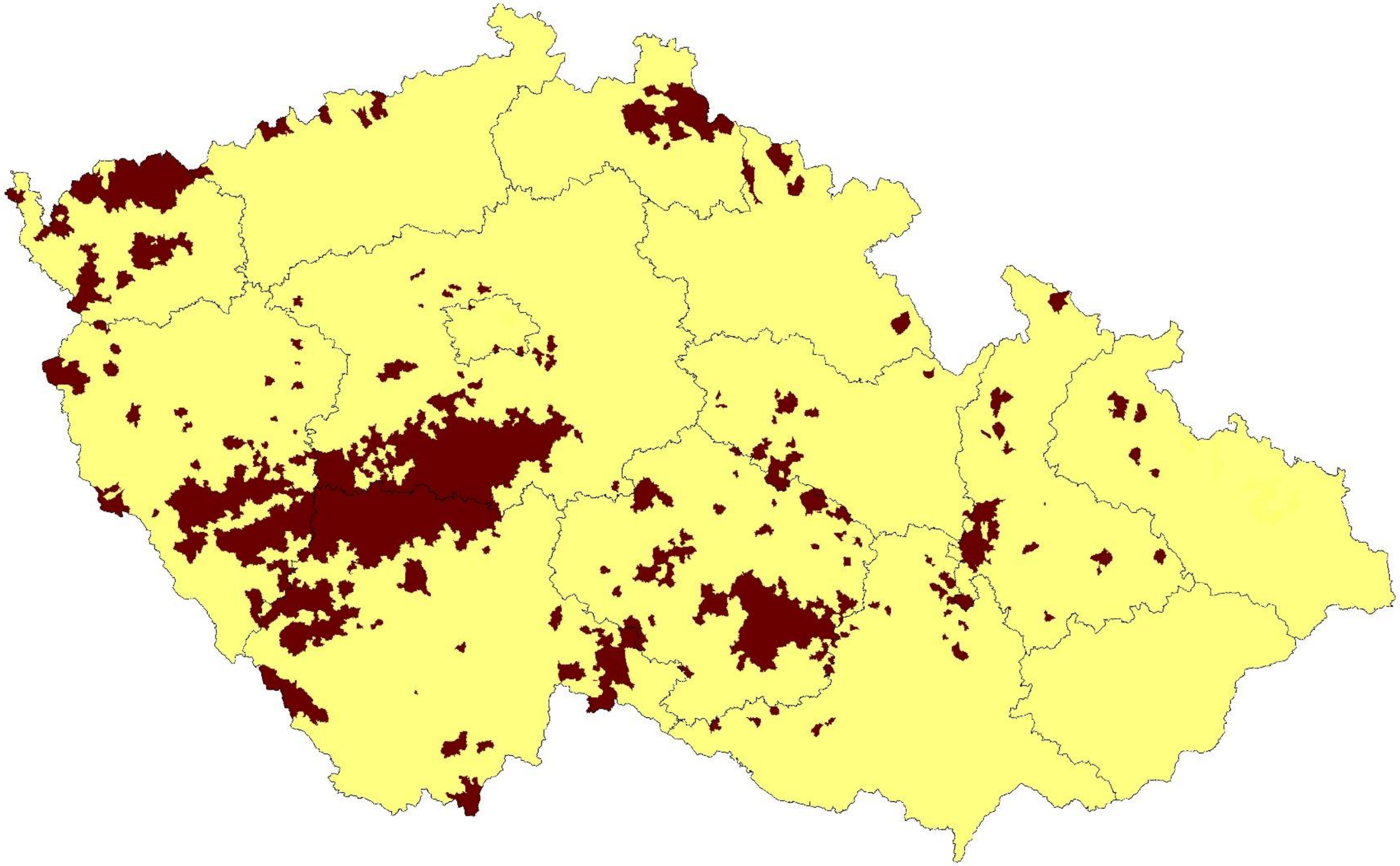
1) **workplace is located on an underground or ground floor of the building**, except for
- building with construction permit issued after 28 February1991;
- building situated in the landscape so that all its perimeter structures are separated from the subsoil by an air gap where air can circulate freely;
- workplaces or buildings in which anti-radon measures have been implemented, and their sufficient efficacy confirmed by measurement;
- workplace that is a parking lot or garage; or
- workplace with a sub-cellar under its entire floor plan and without direct contact with a basement floor;

2) person who performs an activity during which a workplace with possible increased exposure to radon is operated, a natural person performs the work

3) workplace on a basement or ground floor of a building is located in a municipality where the likelihood of exceeding **the reference level 300 Bq/m3** for the radon average activity volume concentration **is greater than 30 %.** (exhaustive list of municipalities is given in Annex)

Radon prone areas in the Czech Republic

Municipalities where the likelihood of exceeding the reference level 300 Bq/m3 for the mean indoor radon concentration in workplaces is greater than 30%



Radon in workplaces - Czech approach to EU BSS implementation, Fojtíková, Ženatá, Timková
Radiation Protection Dosimetry (2017), vol. 177, No 1-2, pp. 104-111

Indoor radon and radon decay products measurement categories in workplaces

- **Preliminary measurement performed in underground workplaces –** short-term or grab sampling measuring techniques applied to avoid exposures to extremely high radon concentration

- grab sampling methods need to be tailored to specific aerosol conditions – **appropriate filters eliminating of aerosols entry into the detection volume need to be applied otherwise the overestimation of 30 to 40% can be observed**

- **Basic method – annual mean indoor radon concentration determination using integrating measuring technique**
  - system of methods and procedures **dependent on human activities** in workplaces
  - long-term mean values of radon concentration assessment – integral measuring methods (SSNTD, electret IC)
  - standard exposure period – 1 year (two measurement periods of integral measurement in underground workplaces such as caves and public access mines reflecting seasonal radon concentration variations – 1st period 1. 4. –30. 9. and 2nd period 1. 10. –31. 3.)
  - individual **influencing factors** (occupational time, number of workers, amount of raw materials and products handled; ventilation and heating regime, ventilation and air-conditioning equipment operation etc.)

- **Repeated measurement**
  - if the reference level is exceeded (**>300 Bq.m^{-3}**) repetition of long-term measurement is performed accompanied with continuous radon concentration measurement enabling us assessment of individual exposures of workers during working hours
  - short-term continuous measurements – minimal exposure of one week (Continuous Radon Monitors) – variety of measuring techniques available on the market with variable technical specifications

Indoor radon and radon decay products measurement categories in workplaces

- **Repeated measurement in a calendar year**

- if there is a possibility of the effective dose reference level 6 mSv exceeding repetition of long-term measurement is performed accompanied with continuous radon concentration measurement enabling us assessment of individual exposures of workers during working hours in every single calendar year

- **Technical specifications** according to recommended methodology issued by National Authority (State Office for Nuclear Safety; SÚJB/OS/3924/2018)

- **continuous monitors certified according to Metrology Act, Act No. 505/1990 of Coll.** - **legally controlled measuring instrument** conforming defined legal metrological requirements
- Dynamical range
- Minimal detection activity
- Response time to change in radon concentration in air
- Overall measurement uncertainty at the level of 300 $Bq.m^{-3}$

- **Special measurement**

- advanced measuring techniques utilization in order to assess the site specific dose conversion factor based on EEC measurement and **unattached fraction f_p determination**
- **Short-term continuous measurement of active aerosols spectra or non-active aerosol conditions and calculation of site specific dose conversion factor**
- **Radon diagnosis (combination of radiometric and non-radiometric measuring methods to identify sources and radon entry points including blower door test and air-exchange rate measurement)**

Simplified individual effective dose assessment procedure

Assuming **2000 working hours per year** and standard aerosol conditions in the workplace represented **by equilibrium factor F=0.4**, the dose estimate can be derived

$$E = \frac{\bar{a}_{v,Rn} . T}{2MBq \cdot h / m^3} .6mSv \qquad E = \frac{\int a_{v,Rn}(t).dt}{2MBq \cdot h / m^3} .6mSv$$

- *E* (mSv) individual annual effective dose
- *T* – exposure time (2000 hours)
- $a_{V,\mathrm{Rn}}$ – mean radon concentration during working hours

Mean radon concentration during working hours can be estimated using annual mean radon concentration assessment from SSNTD corrected with **occupational factor derived from short-term continuous radon measurement**

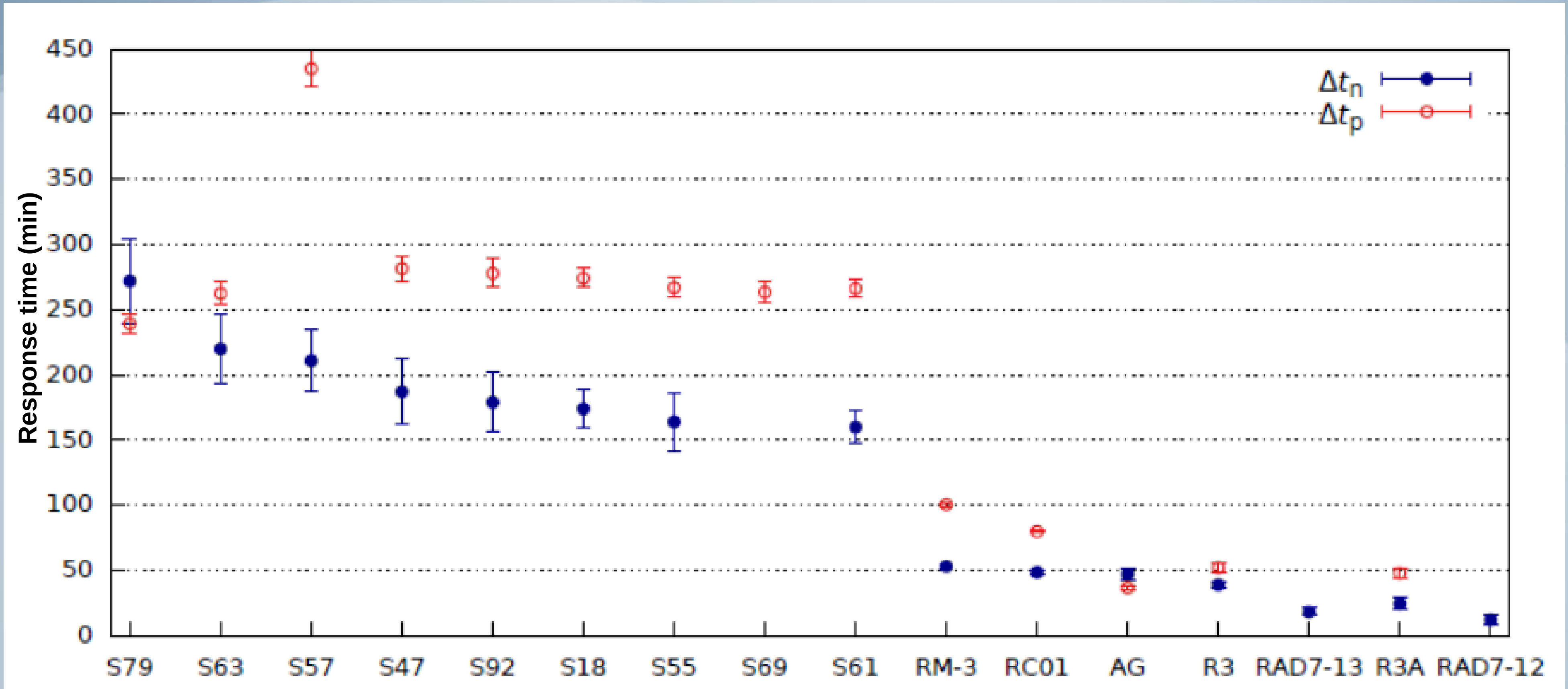
Individual cave factor

$$j = 0{,}9107e^{1{,}7082fp}$$

Basic measurement method - Solid State Nuclear Track Detectors - integrating detection system RAMARN

Detection foil Kodak LR115
National Institute for Nuclear, Chemical and Biological Protection

QA/QC proficiency testing of continuous radon monitors – time response to changes in radon concentration



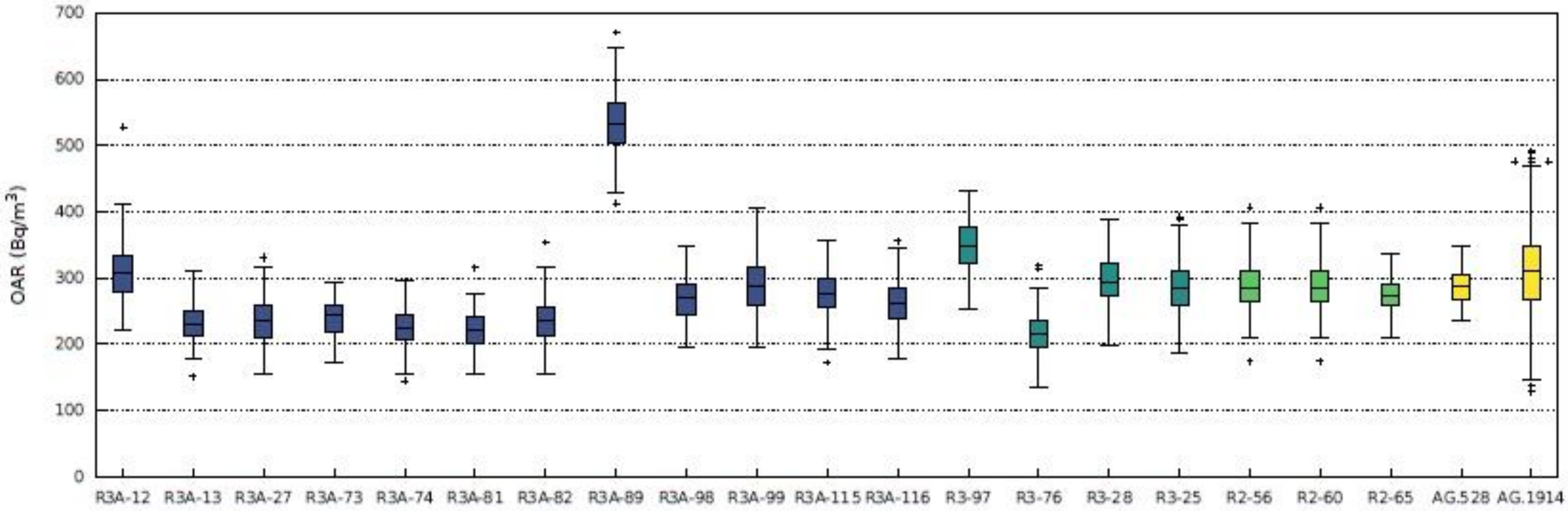
$$\Delta t_n = -\frac{1}{n_n} \ln(0,05)$$

Build-up response time - time needed to reach 95% of radon concentration steady state

$$\Delta t_p = -\frac{1}{n_p} \ln(0,05)$$

Drop-in response time - time needed to reach $a_0 + 0.05*(a_{stac} - a_0)$

QA/QC Measurement campaign – continuous radon monitors

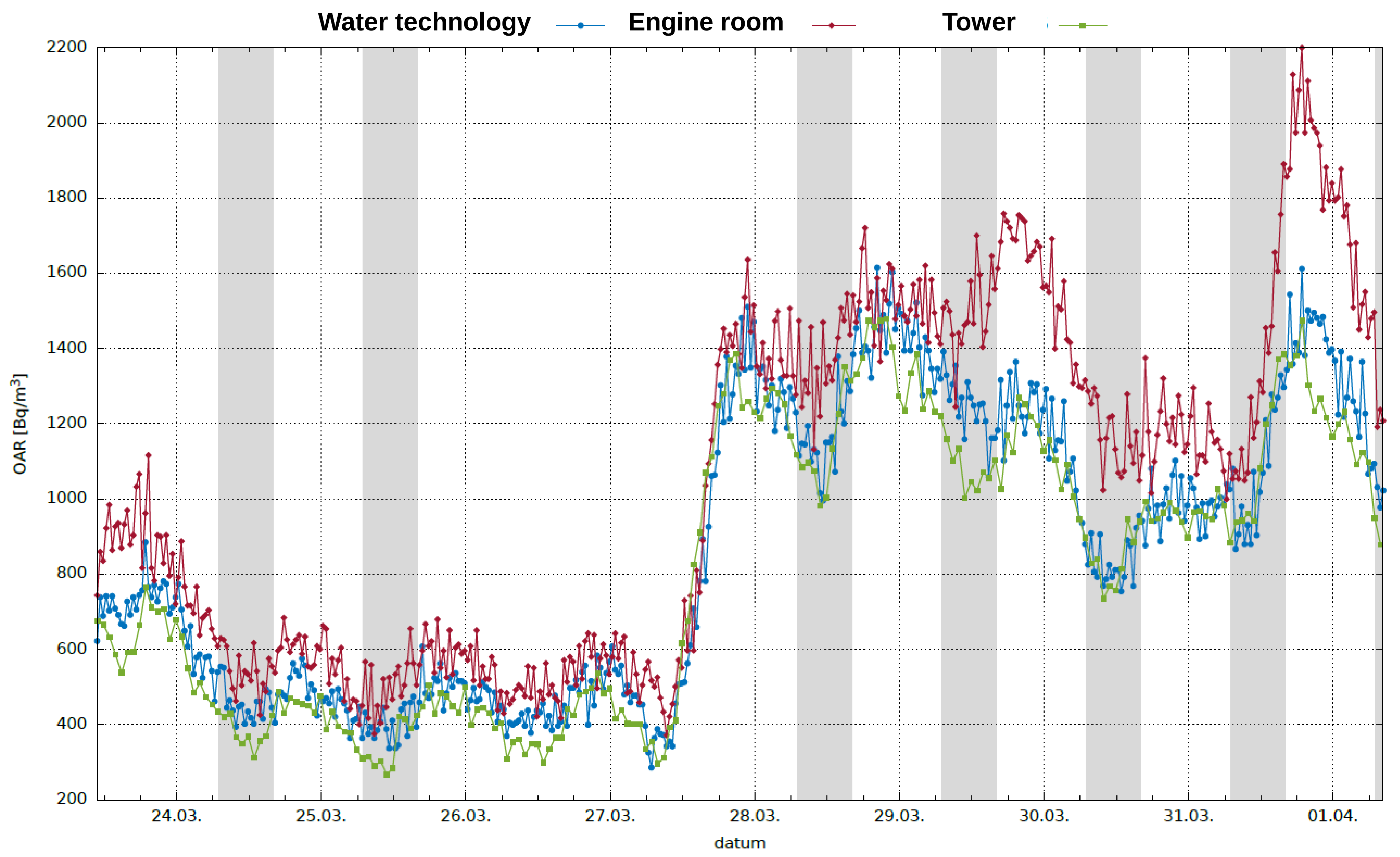


Measurement campaign

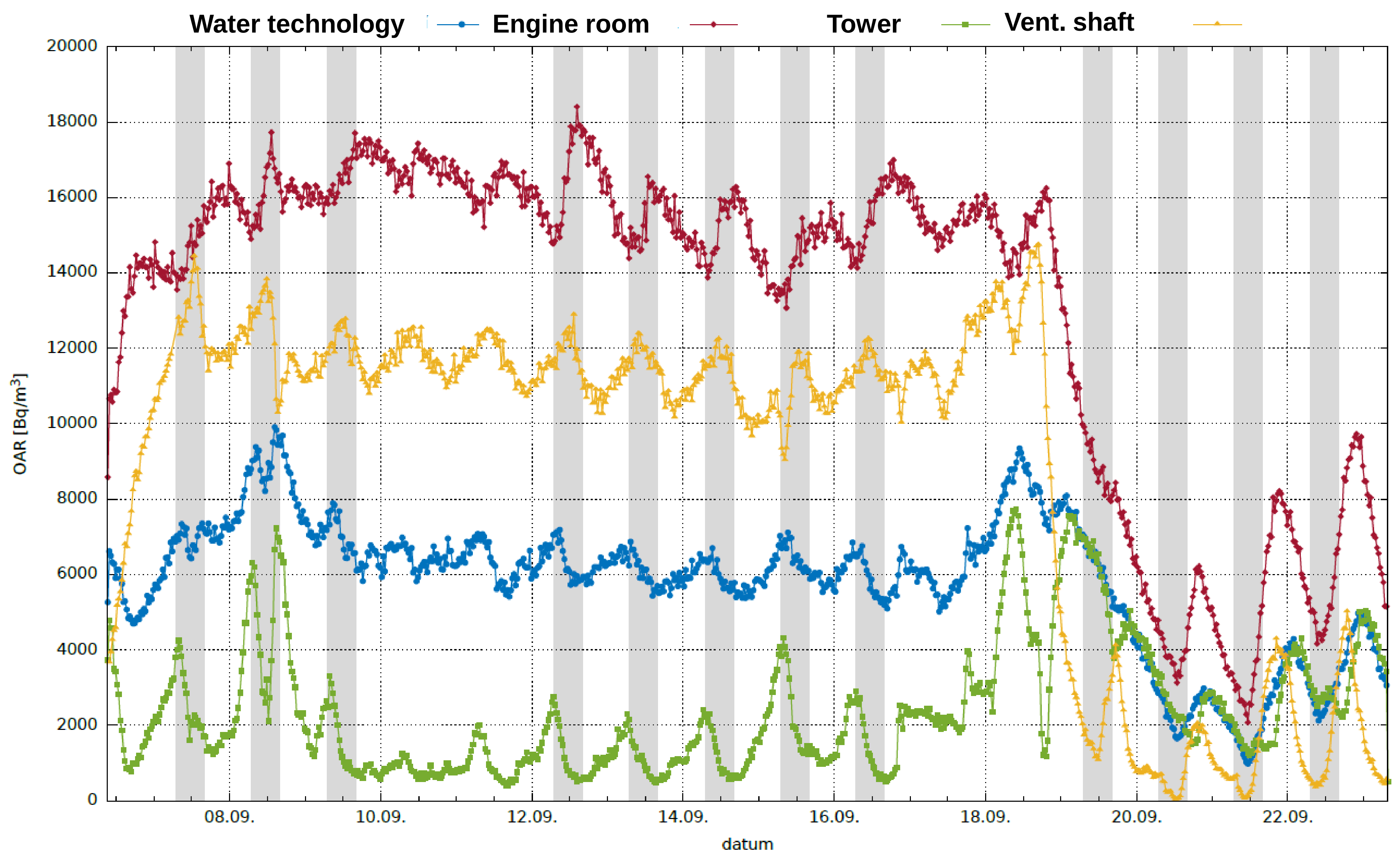
- 5-days exposure in radon calibration facility (radon chamber) under standard aerosol conditions simulating common atmosphere in buildings
- **Reference radon concentration – 310 Bq.m-3**
- Average air temperature – 22 °C
- Average relative air humidity – 34%
- Average atmospheric pressure – 993 mbar

Radon workplace – Underground facility - Civil protection shelter

Radon workplace - Civil protection shelter (continuous record 23.3. – 1.4.)



Radon workplace - Civil protection shelter (continuous record 6.9. – 23.9.)



Radon workplace – Underground facility - Civil protection shelter

Measurement location	Mean indoor radon concentration (Bq.m-3)		Correction factor
	Whole exposure	Working hours	
Tower	818	797	0.98
Water technology	912	491	0.57
Engine room	1098	610	0.57

Measurement location	Mean indoor radon concentration (Bq.m-3)		Correction factor
	Whole exposure	Working hours	
Tower	2346	2936	1.26
Water technology	5687	7322	1.23
Engine room	13060	14917	1.13
Ventilation shaft	8666	11261	1.27

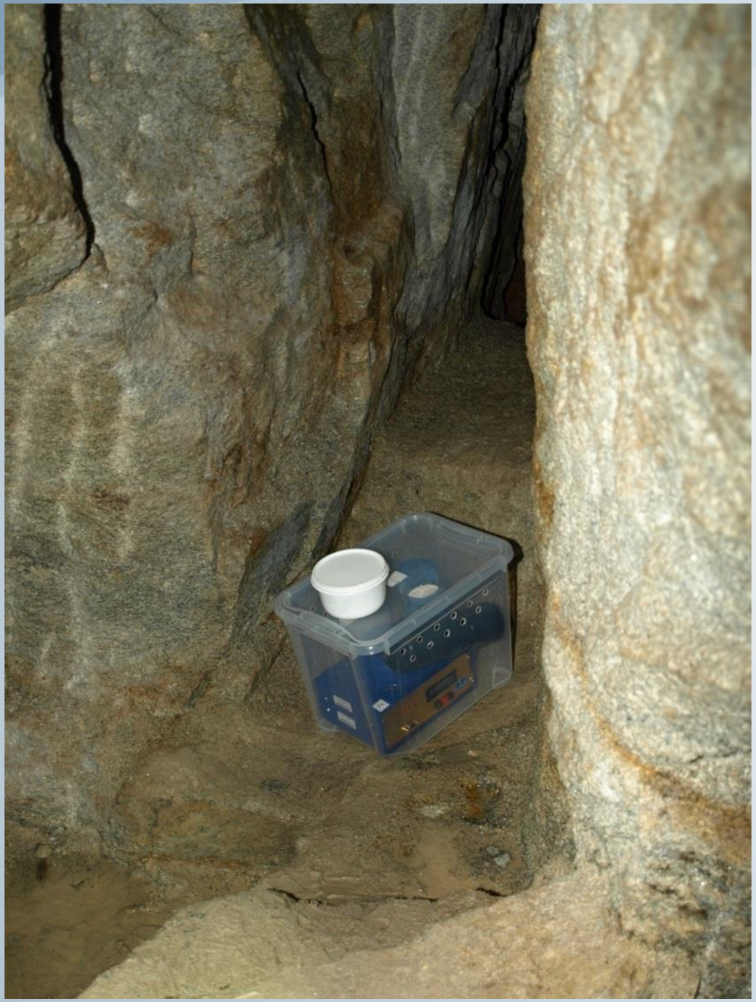
Annual effective dose
15.8 mSv

- Day shifts schedule
- Working positions time image
- Site specific dose conversion factor needed

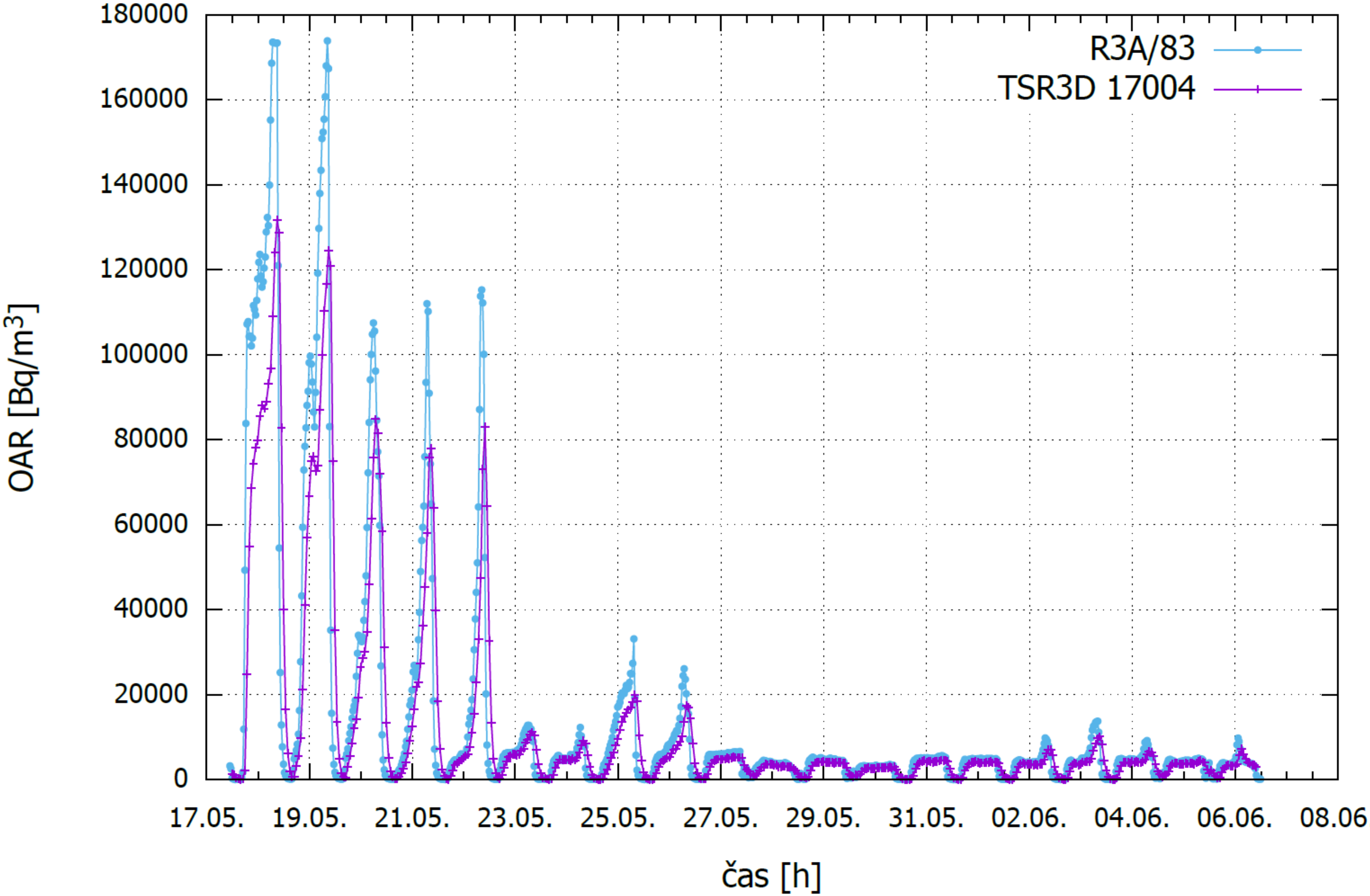
Winter season average correction factor: 0.71

Summer season average correction factor: 1.22

Radon workplace – Underground workplace – old tin mine open to the public



Radon workplace – Underground workplace – old uranium prospection shaft open to the public



R3A/83
TSR3D 17004
OAR [Bq/m3]
180000
160000
140000
120000
100000
80000
60000
40000
20000
0
17.05.
19.05.
21.05.
23.05.
25.05.
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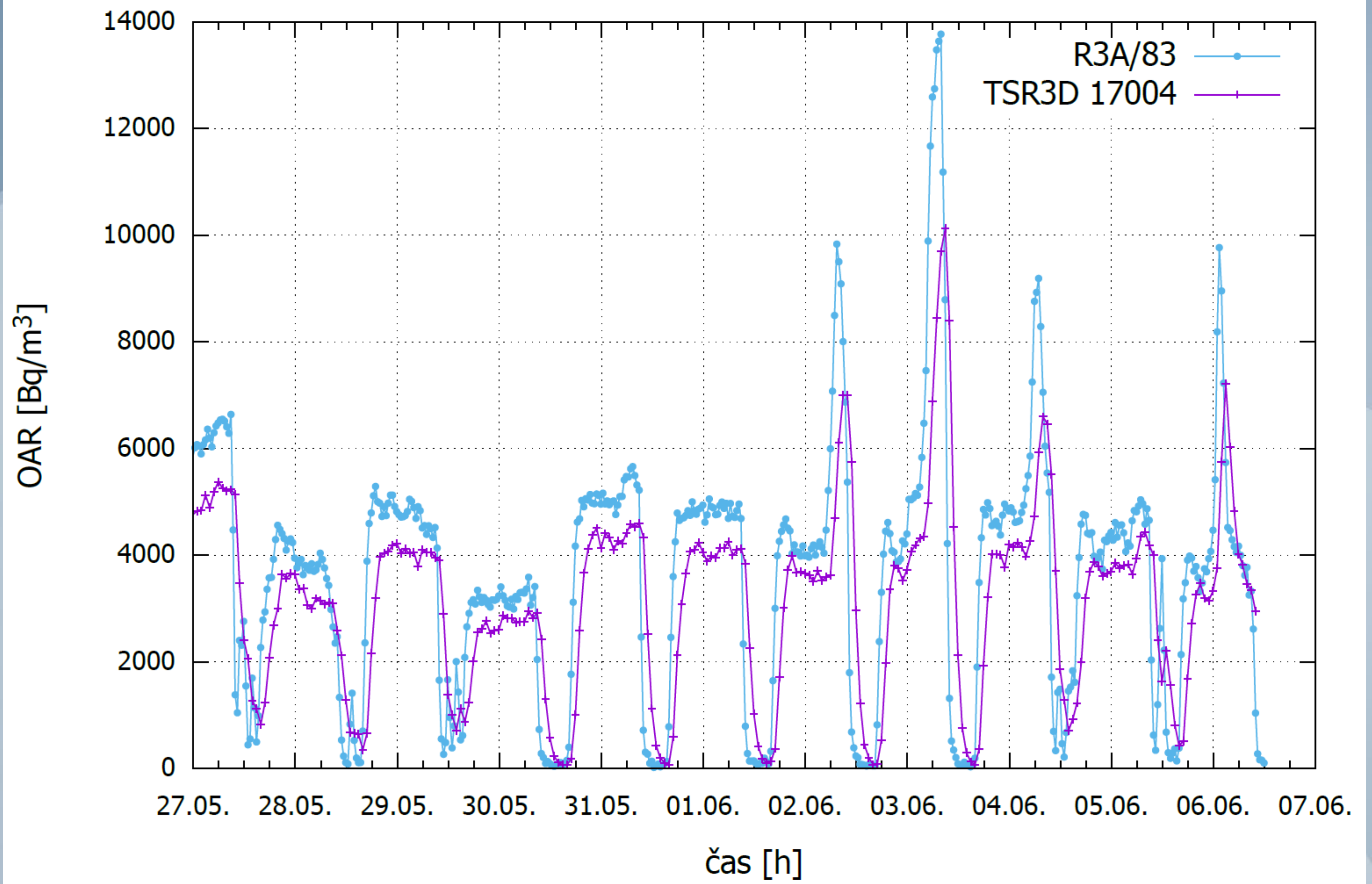

R3A/83
TSR3D 17004
OAR [Bq/m3]
0
2000
4000
6000
8000
10000
12000
14000
27.05.
28.05.
29.05.
30.05.
31.05.
01.06.
02.06.
03.06.
04.06.
05.06.
06.06.
07.06.
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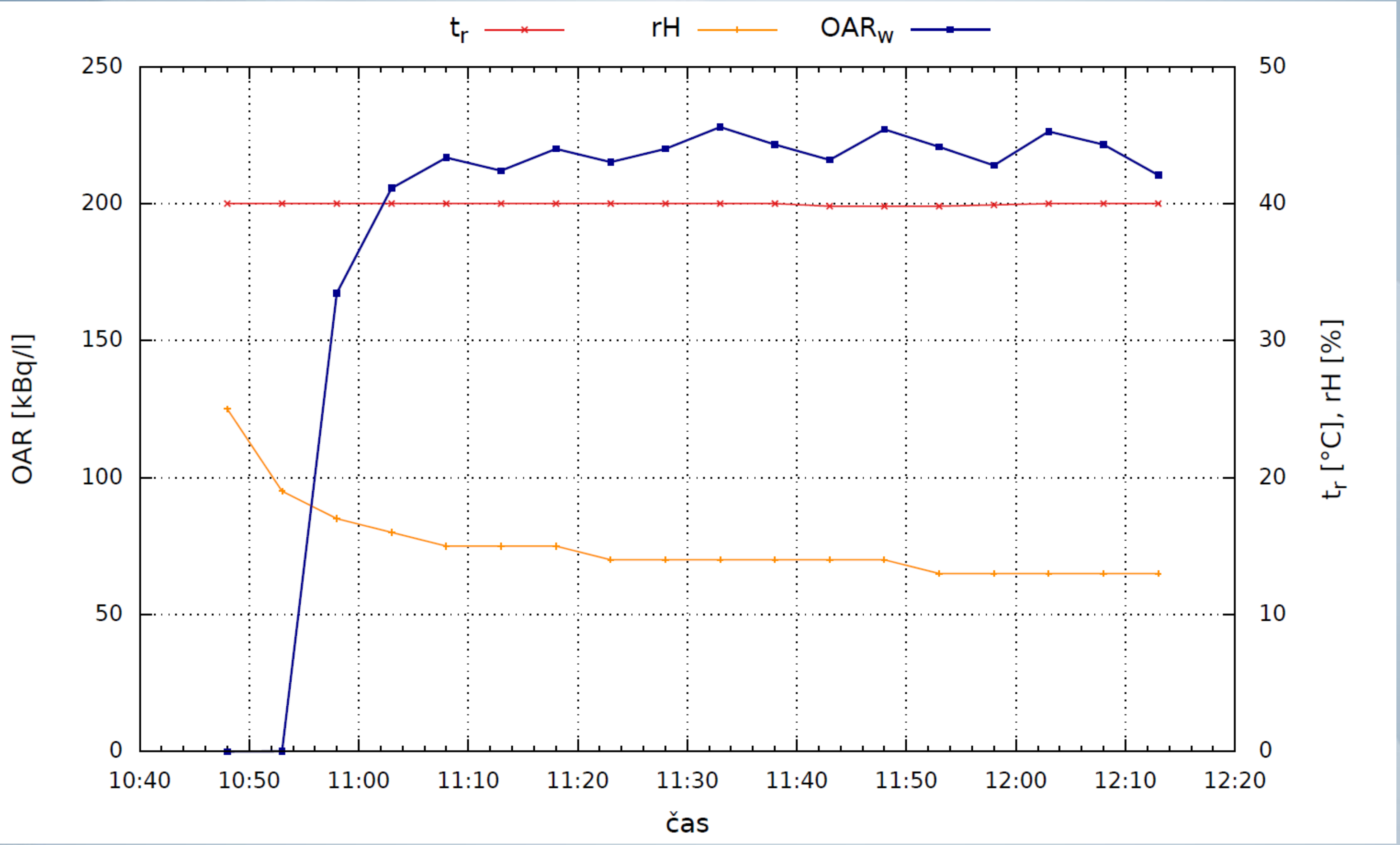
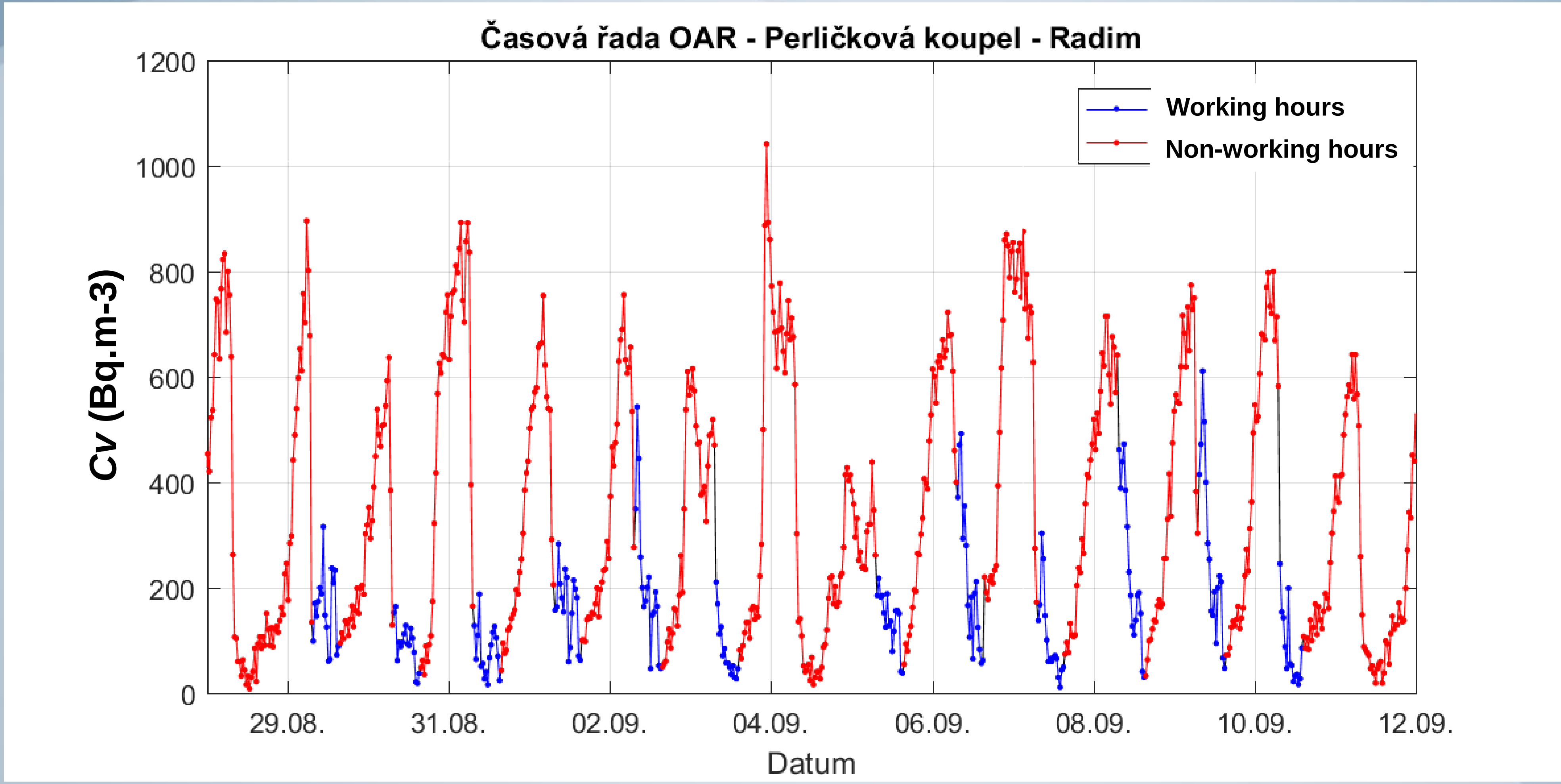
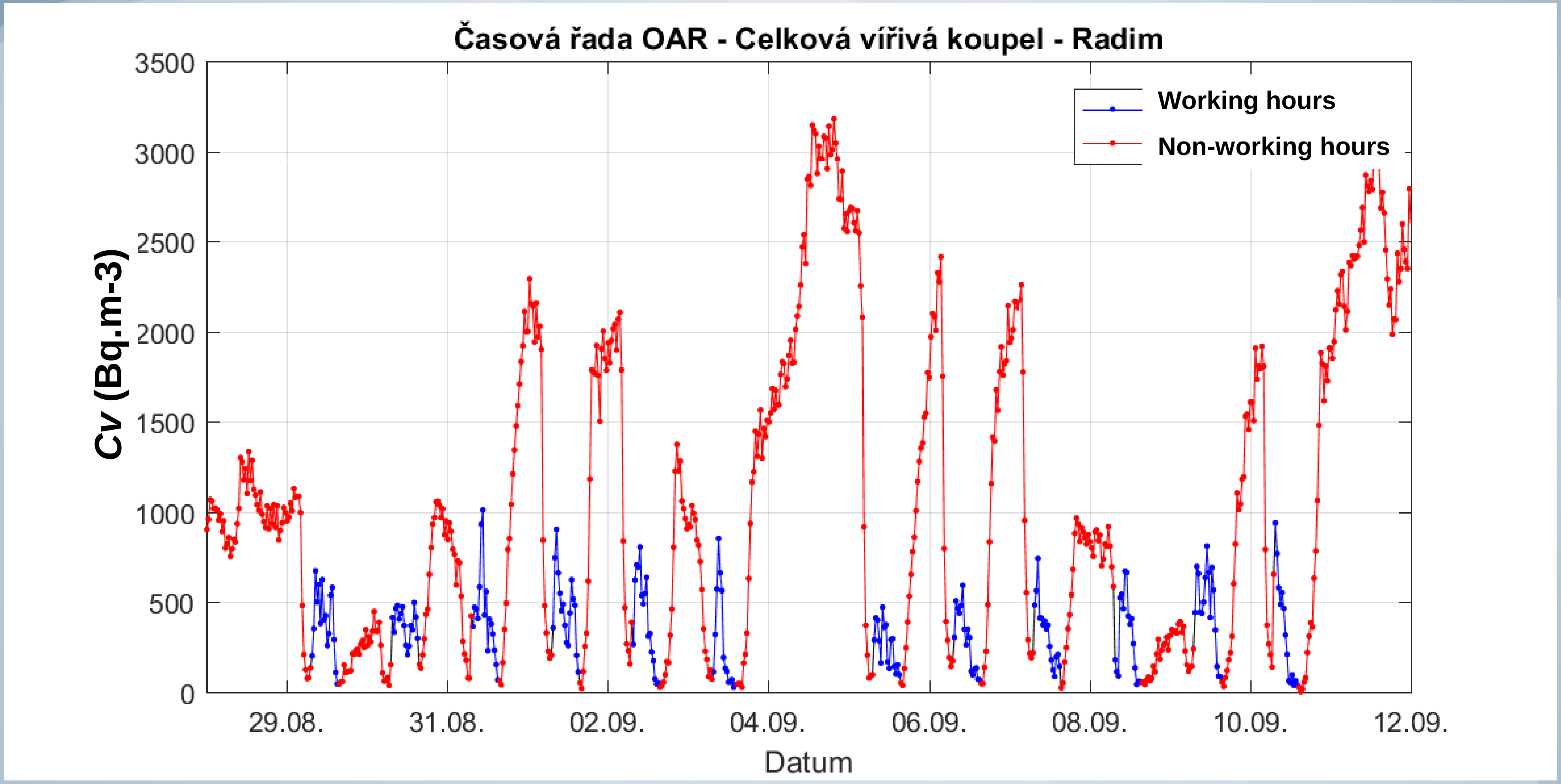
Radon workplace – spa – radon-in water concentration continuous record



Radon workplace – spa – radon concentration continuous record (pearl-bath) with identification of working hours

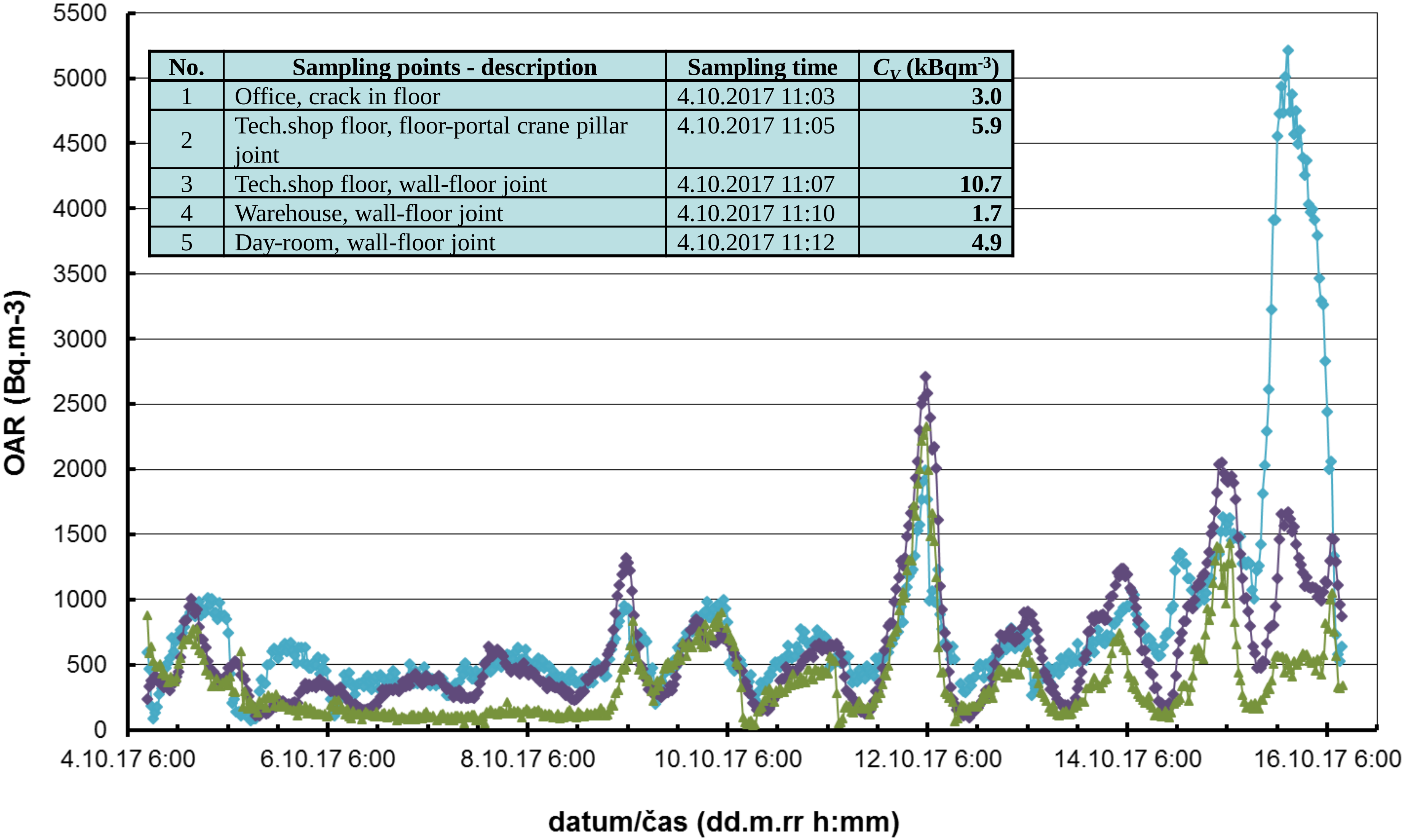


Radon workplace – spa – radon concentration continuous record (whirling-bath) with identification of working hours



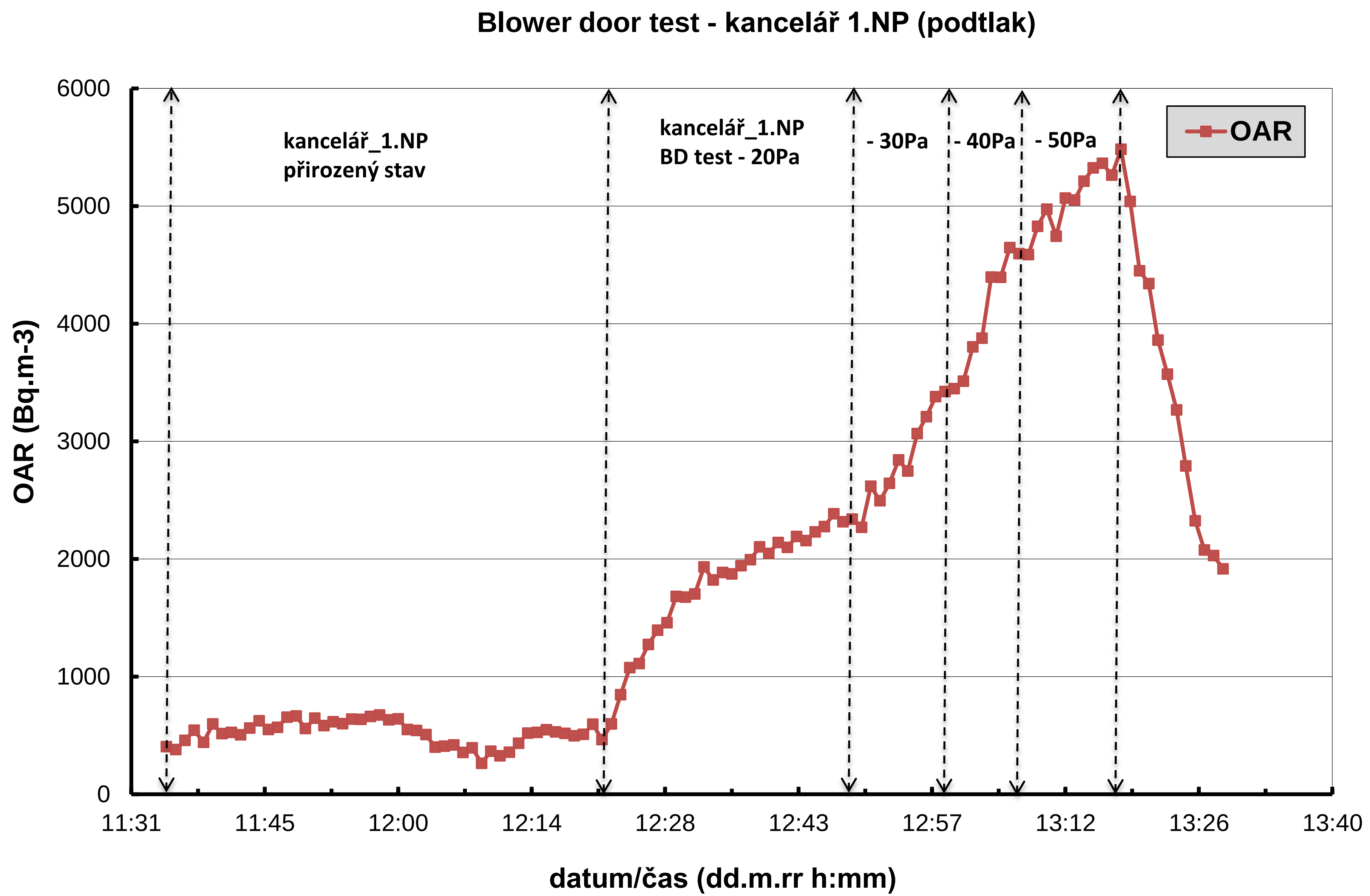
Radon workplace in radon prone area – manufacturing facility

Radon workplace in radon prone area – manufacturing facility



No.	Sampling points - description	Sampling time	C_V (kBqm^{-3})
1	Office, crack in floor	4.10.2017 11:03	**3.0**
2	Tech.shop floor, floor-portal crane pillar joint	4.10.2017 11:05	**5.9**
3	Tech.shop floor, wall-floor joint	4.10.2017 11:07	**10.7**
4	Warehouse, wall-floor joint	4.10.2017 11:10	**1.7**
5	Day-room, wall-floor joint	4.10.2017 11:12	**4.9**

Radon workplace in radon prone area – manufacturing facility



Lessons learned and future challenges

- **Measuring techniques and procedures appropriate for specified exposure conditions – technical specifications of CRM**

- **Site specific dose conversion factors application – crucial role of active aerosol spectra measurement and unattached fraction determination**

- Apparent conflicts between professional experience and recommendations on air-exchange rate in buildings (issued by National Institute of Public Health) and Czech standards requirements given in Thermal Protection of Buildings; **0.3h-1 (minimal value for occupied rooms); 0.1h-1 (minimal value for unoccupied rooms)**

- **New requirements on evaluation of energy performance of buildings in the Czech Republic (EU)** – implementation of the revised European Union Directive 2010/31/EU on the energy performance of buildings – changes associated with energy certification of buildings
  - amended legislation needs to be applied on all types of buildings, including new build houses and existing dwellings (graded approach is defined)
  - „lack of harmonization“ with public health care programs focused on IAQ requirements, including Radon Program – Action Plan (2010-2019) coordinated by State Office for Nuclear Safety **(needs to be addressed in future Action Plan)**

Thank you for your attention!