Comprehensive investigation of radon exposure in Austrian tourist mines and caves

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Legal basics

- 2008: „Ordinance on Exposure due to Natural Radiation Sources" (NatStrV, BgBl.II, Nr. 2/2008) – implementation of the 96/29/Euratom guidelines
- Regulation for **occupational exposure** due to **natural radiation sources**
- **Specifies workplaces** with potentially enhanced exposures caused by natural radionuclides
- List of workplaces with **potentially enhanced radon exposures**:
    - Water works
    - Radon spas
    - Underground workplaces
    - **Tourist mines and caves**
- Compulsory **dose evaluations** at those workplaces, if radon concentration is >400 Bq/m³
- 1-6 mSv/a: occupationally exposed category B
- 6-20 mSv/a: occupationally exposed category A (requirment for permanent dose evaluation and medical checkups)
- Annual dose limit: **20 mSv/a** (in justified exceptional cases 50 mSv in 12 consecutive months, if in 60 consecutive months 100 mSv is not exceeded)

The Study - Introduction and Motivation

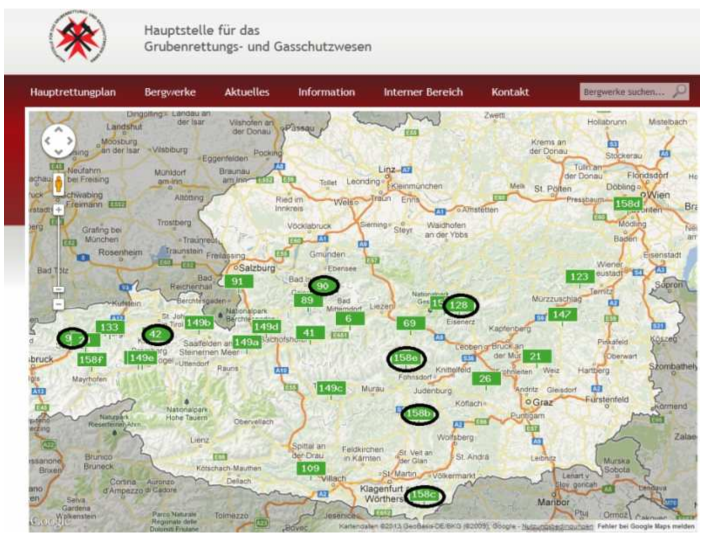
- **Tourist mine**: artificial, already shut down or still partly active mines adapted for tourist visits
- **Tourist cave**: Natural underground caves, adapted with paths, steps, lights
- No comprehensive surveys on radon exposure of workers in tourist mines and caves in Austria – pilot study to assess the situation in Austria
- Funded by the Ministry of Agriculture, Forestry, Environment and Water Management (BMLFUW)
- Collaboration between Austrian Agency for Health and Food Safety (AGES), Austrian Workers' Compensation Board (AUVA), GT-Analytics
- **Main goals**:
  - Identify **main parameters** influencing radon concentration in mines and caves
  - Evaluate **Temporal variation** of radon concentration in mines and caves
  - Evaluate and establish a **sound method** for such measurements and dose estimations
  - Estimate **dose** (caused by radon) for the workers

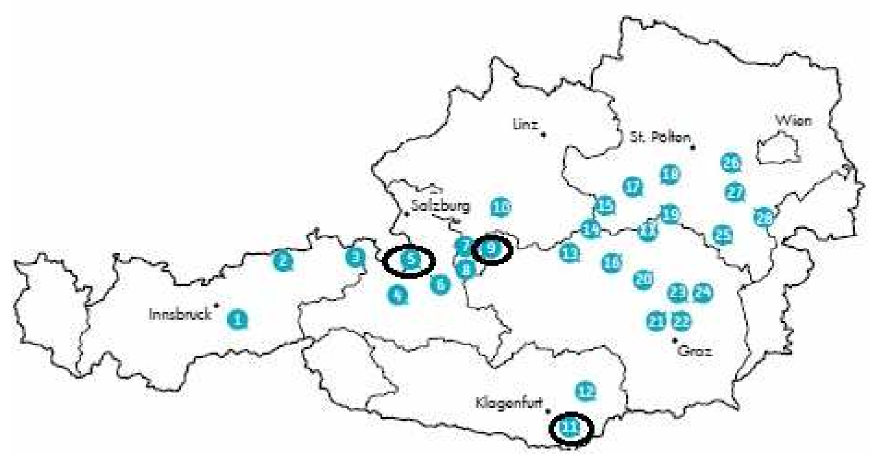
The Study – Materials and Methods I

- 30 tourist mines and 28 tourist caves exist in Austria
- According to the availability of measurement instruments and financial framework
  6 mines and **3 caves** were selected

  (based on broad geographical and geological distribution, variety of raw materials and cave types, number of visitors, opening hours, willingness of operators to take part)

- 3 karstic caves (1 ice cave, 1 water-bearing cave, 1 flowstone cave)
- 1 salt mine, 1 copper mine, 2 silver mines, 2 iron-ore mines





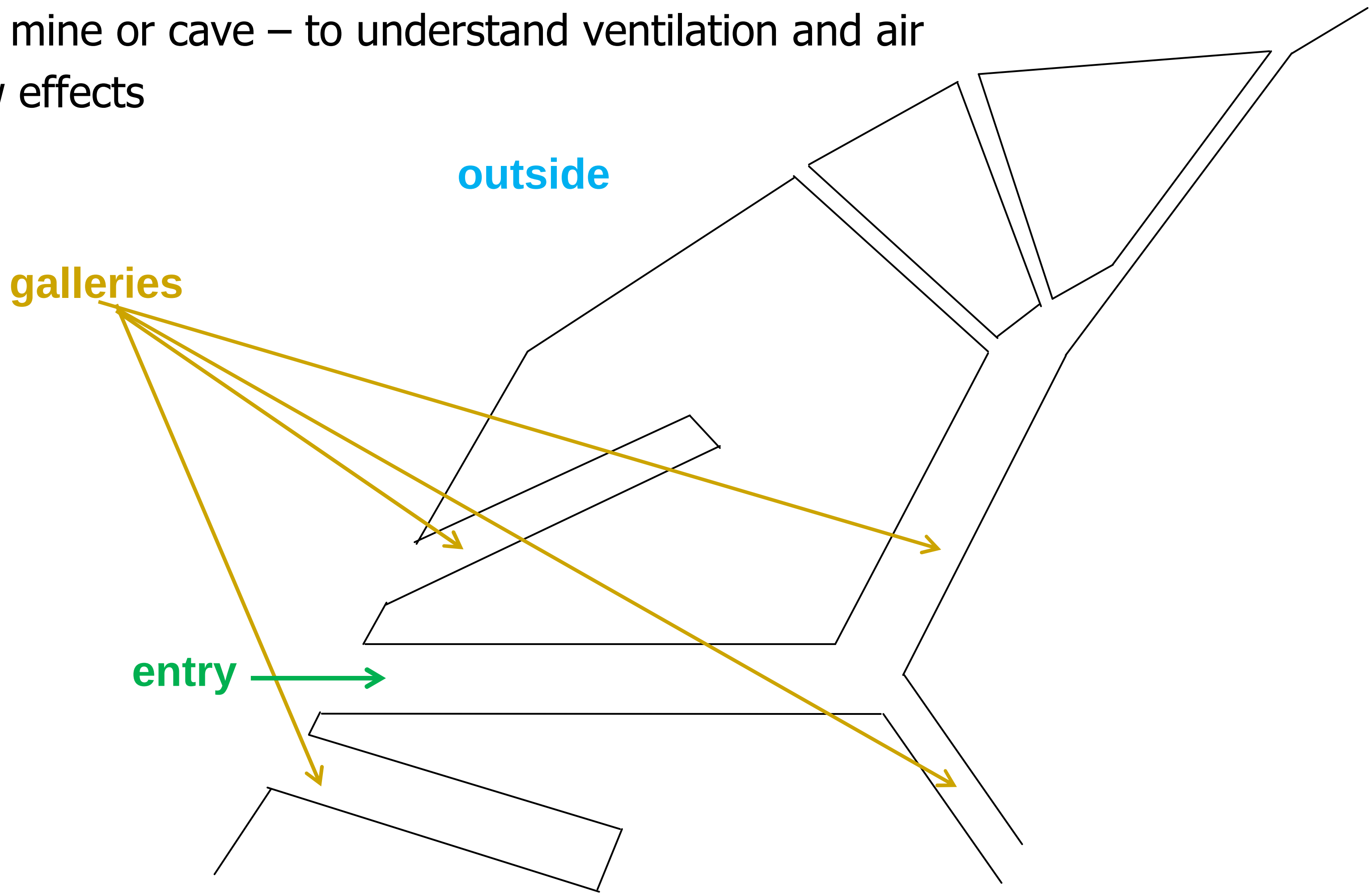
The Study – Materials and Methods II

- In each of the selected mines/caves: Measurement at 5 to 10 representative locations along the „visitors' route" for **6 months**, continued at 1 to 3 selected locations up to **1 year** (because of limited number of active measurement instruments)
- Total time of measurements: 2008 to 2010
- Measurement devices: **32 continuous** (time-resolving) **radon monitors** (6 AlphaGuard, 2 EQF 3120, 1 RTM 2100, 14 Radim3A, 9 Radim5)
- Protection in boxes (dust, water etc.)
- **Air pressure** and **temperature** was recorded (and compared to outside air)
- **Thoron** (EQF and RTM) and **equilibrium factor F** (EQF)
- **Validation measurements**: All instruments for 3 weeks in one mine (with reference AlphaGuard) → correction factors (if necessary)



Side note

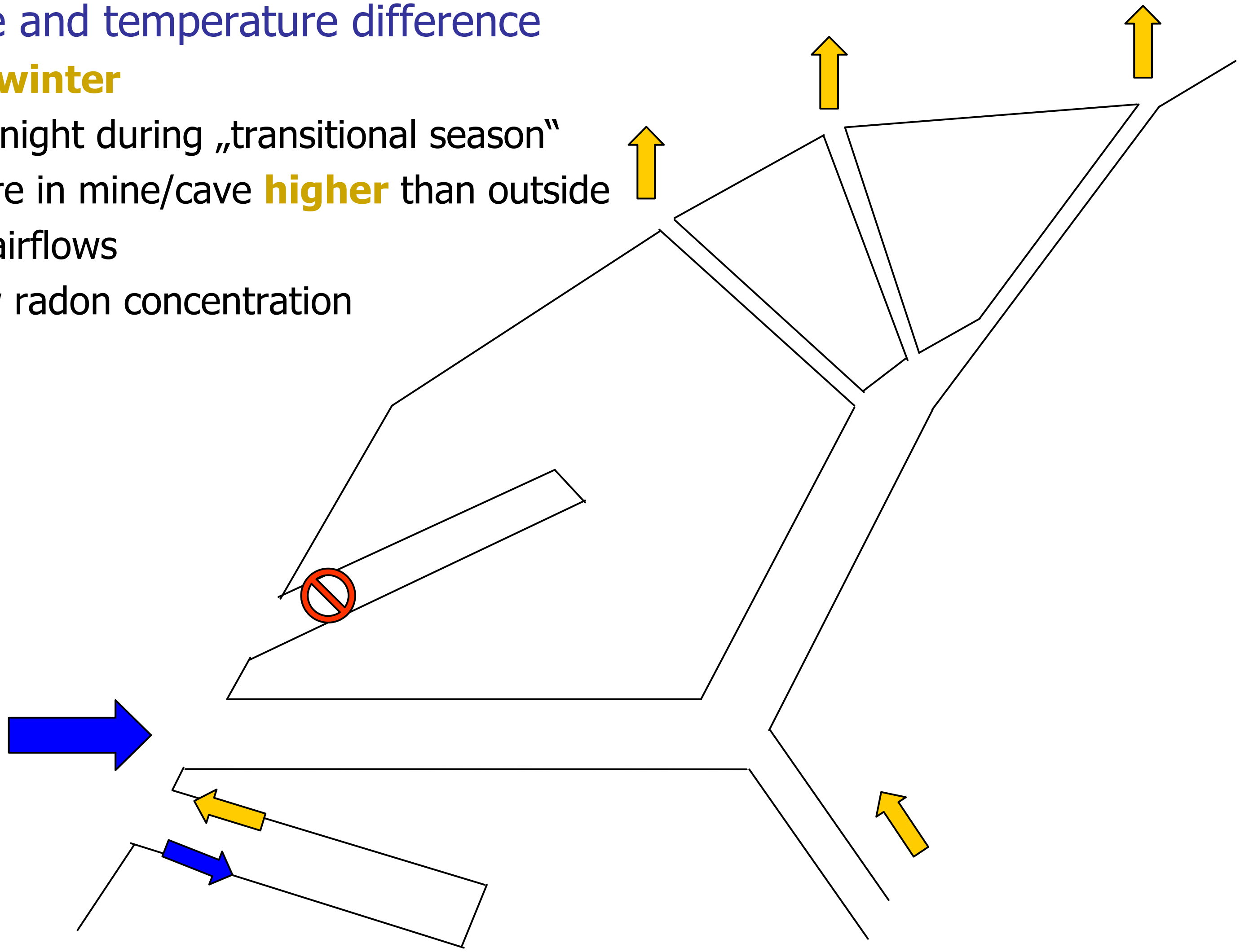
Simplified illustration of cavities (structure of galleries) in a mine or cave – to understand ventilation and air flow effects



Side note

➢ structure and temperature difference

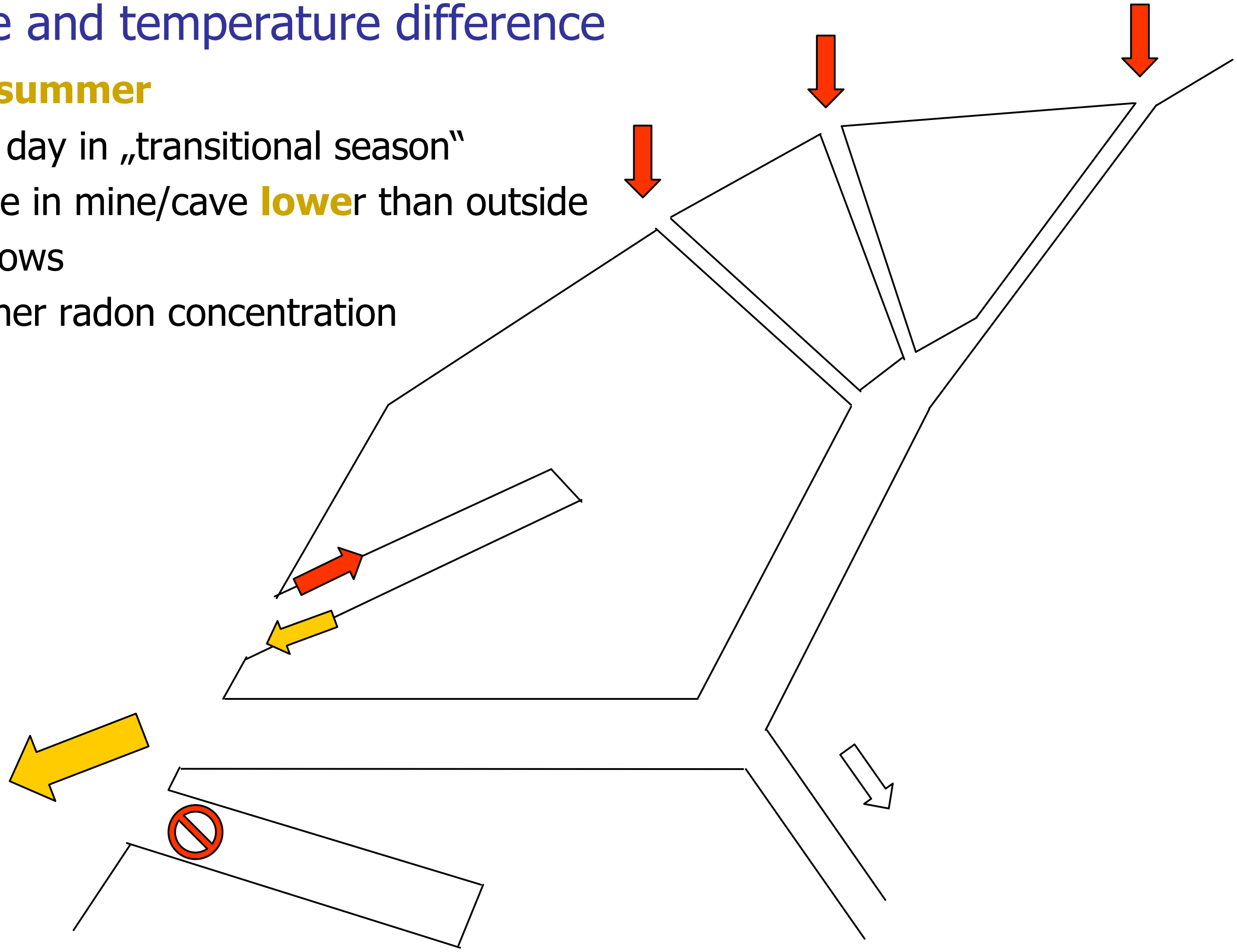
- air flow in **winter**
- and in the night during „transitional season"
- temperature in mine/cave **higher** than outside
- downcast airflows
- usually low radon concentration



Side note

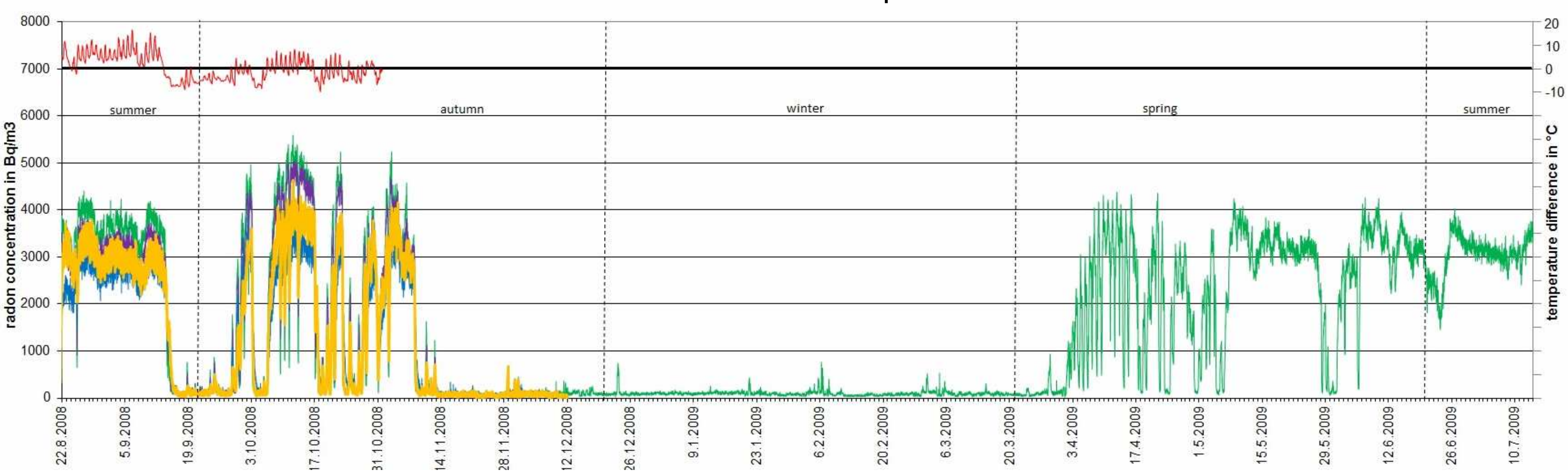
➢structure and temperature difference

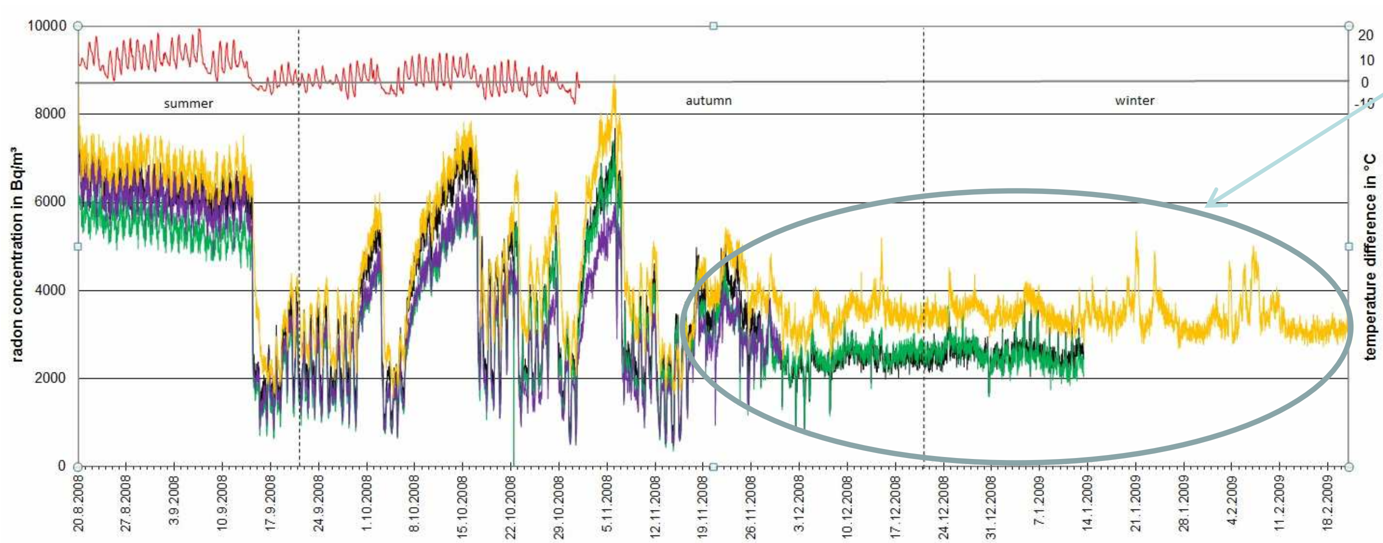
- air flow in **summer**
- and during day in „transitional season"
- temperature in mine/cave **lowe**r than outside
- upcast airflows
- usually higher radon concentration



Examples: mines

Iron-ore mine, 1 year measurement
constant temperature about 8°C





Closing of gallery door during winter, to prevent cooling of the mine

Silver mine,
6 months measurement
constant temperature
about 9°C

Results of Radon-Measurements

- Averaged radon concentrations in the mines and caves ranged from about 230 Bq/m^3 (ice cave) to 16 300 Bq/m^3 (one part of silver mine)
- **Maximum** measured radon concentration 60 kBq/m^3 (silver mine, winter! – specific situation, stack-effect, air from deeper galleries)
- Overall trend: lower radon concentration in winter

Object	Mean Rn222-conc. [Bq/m^3] without winter
Caves	960
Salt mine	1300
Iron ore mines	3000
Silver mines	4200
Copper Mine	4900

Results of Radon-Measurements

- For dose evaluations for workers – „representative" or conservative radon concentration has to be used (NatStrV)
- Important to evaluate the **variability of radon concentration** in the objects → to define measurement time and e.g. seasonal correction factors or „conservative factor"
- **Ratios of 90%-quantile and mean** were calculated for all seasons and entire year for each mine or cave
- Ratios lay between 1.2 and 3.9, but mainly below 2. Highest deviations in autumn and in mines with artificial ventilation.

- Comparison between 90%-quantiles for the **total measurement time and only within working hours** (8:00 to 17:00) showed differences within 5% and can be neglected for dose evaluations
- Exception: Mines with artificial ventilation (only turned on during working hours) – and reduce radon concentration significantly

More measurement results

Equilibrium factor:

- Mainly quite low (< 0.2)
- Exceptions in winter in the copper mine (0.54) and iron mine (0.4)
- In salt mine – ventilation is kept very low on purpose to avoid high humidity in the mine – high equilibrium factor (0.7)
- Mean equilibrium factor: 0.23

Thoron:

- Non of the measurements with EQF showed relevant thoron contribution in the spectra
- In 3 objects thoron contribution was measured with RTM
- Highest thoron concentration in salt mine – about 75 Bq/m^3 (8.6 % thoron contribution)

Main parameters influencing the radon concentration

- **Geology** (incl. „mining product")

- **Structure** of the cavities

- **Temperature difference** outside – inside:
  - Seasonal variations
  - Diurnal variations

- Artificial **ventilation** and gallery (weather) doors

- Air pressure (not significantly observable within this project;
  overlayed with other effects)

- **Water** (not clearly observable within this project)

Dose evaluations

- Radon concentration results were **averaged** for each site, or for parts of the site, which have comparable ventilation and air flow
- Dose evaluations were carried out according to NatStrV
- For determining the „**representative radon concentration**" of each site several **quantiles** were calculated from the individual radon time series
- Depending on the annual time, the worker spends in this (part of the) mine or cave – different quantiles were used for dose evaluation
- For a short annual time the worker spends in the cave or mine (e.g. only 20h/a), the 90% quantile was used, as it could be that the worker spends all the 20 hours at this working place, when the radon concentration is high.
- If a worker spends e.g. 1000 h/a in this mine or cave, a lower quantile was used, as he can not spend all his working time at the working place at highest radon levels.
- Dose was calculated for **each individual worker**, taking into account the time spent at the working places according to the season

Results of Dose evaluations

- Categorisation for the highest exposed worker in the mine/cave
- Highest: 15.5 mSv/a in copper mine

	Number	<1mSv/a	Kat. B (1-6mSv)	Kat. A (6-20 mSv)
			occupationally exposed	
Tourist caves	3	2	1	
Tourist mines	6		5	1

- Dose for an annual time of worker in the object of 200 h/a

Objekte	Jahresdosis [mSv/a]
Caves	0,9
Salt mine	1,1
Iron ore mines	1,9
Silver mines	3,3
Copper mine	5,4

Summary

- More knowledge about **situation** in tourist mines and caves in Austria
- Characterized **main parameters** influencing the radon concentration
- Better understanding of **seasonal effects** and **time variation**
- With the results (e.g. **conservative factors)** - possibility for shorter and/or passive radon measurements in the future
- **Help** for design and carry out radon measurements and dose assessments in mines and caves (e.g. main points to take into account, possible problems – electricity, ice!, etc.)
- **Intercomparison** of measurement devices under those specific conditions (temperature, humidity)
- **Take into account all work places**! (e.g. also shop, cash desk, wardrobe if connected to the mine/cave)

AGES

Thank you for your attention!