Agenzia nazionale per le nuove tecnologie, l'energia e lo sviluppo economico sostenibile

UNIVERSIDAD D CÓRDOBA

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Physics & metaphysics en gros & en detail

AGES

UPC UNIVERSITAT POLITÈCNICA DE CATALUNYA BARCELONATECH

trace Radon

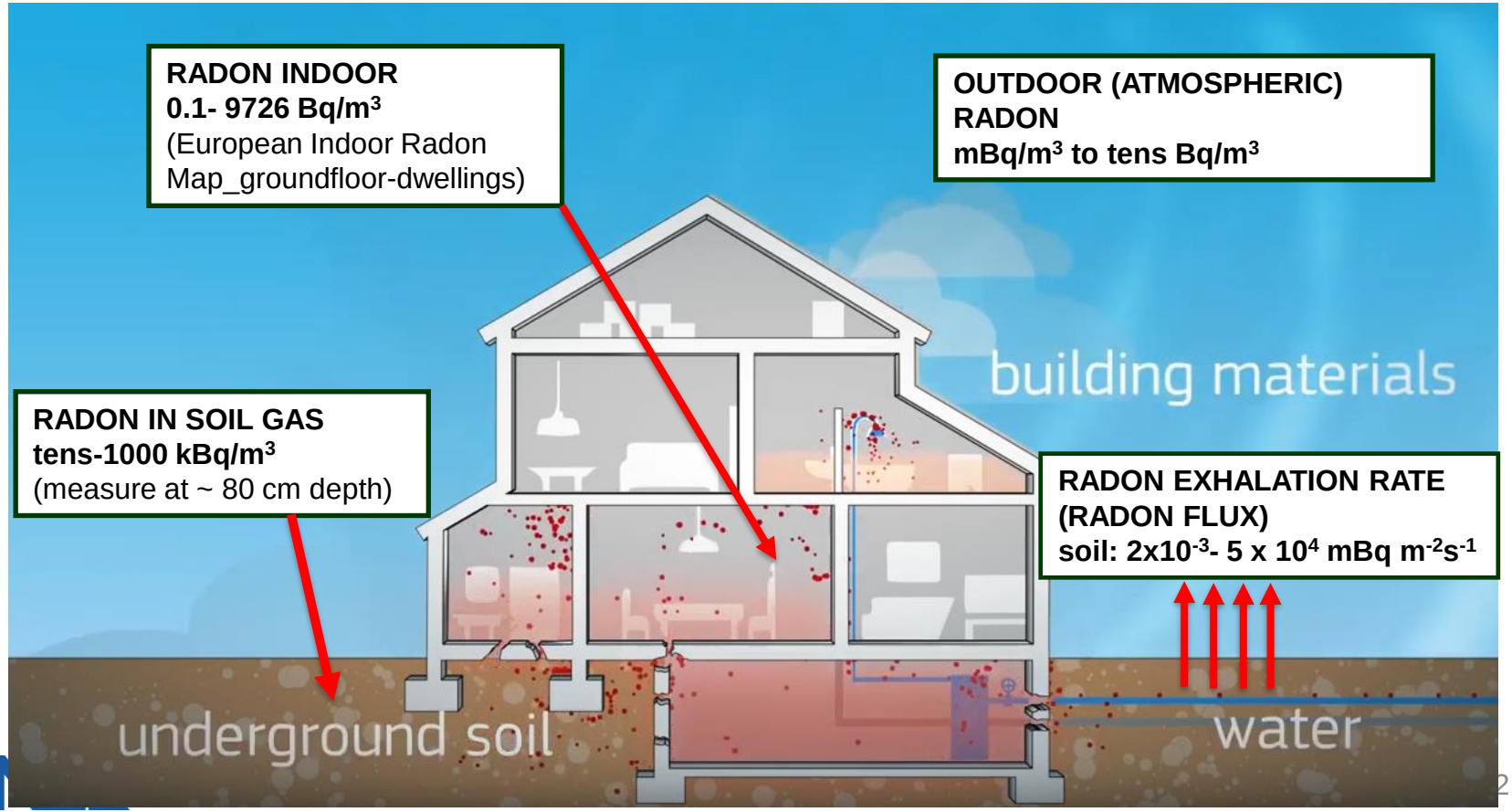
EURAMET

Use of outdoor radon activity concentration and radon flux data for radiation protection applications (WP4)

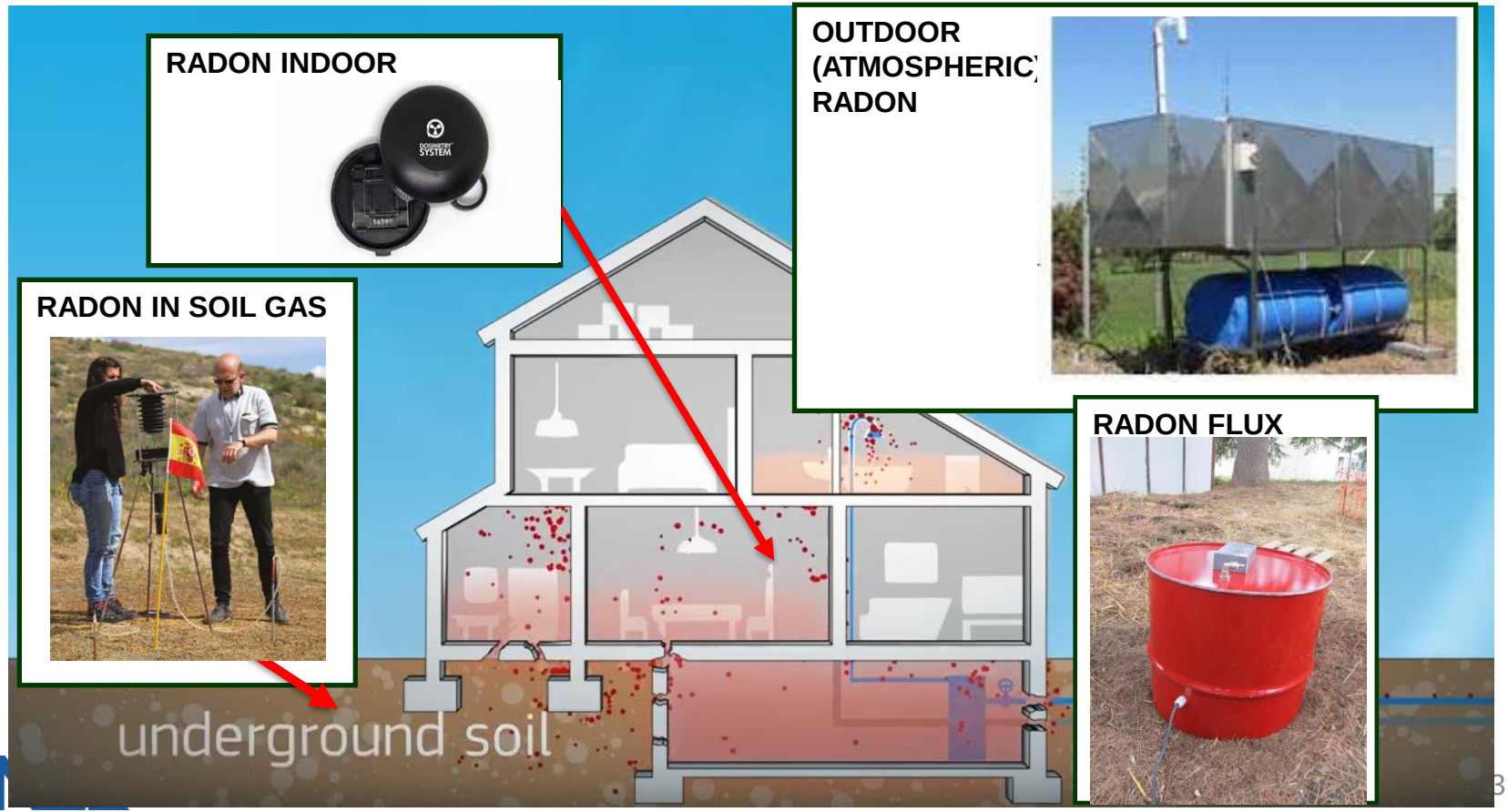
Cinelli G., Gruber V., Baumann S., Celikovic I., Zivanovic M., Pantelic G., Vukanac I., Krneta J., Grossi C., Vargas A., Hernandez Ceballos M.A., Bossew P.

Scientific Workshop_PTB Braunschweig (DE), 14 March 2023

Radon Indoor, Outdoor, in soil gas, flux…



Radon Indoor, Outdoor, in soil gas, flux…



Legal Basis

- Indoor Rn is one of the major cause of lung cancer after smoking_EUROPE'S BEATING CANCER PLAN

Radiation Protection

- Due to the health risk authorities attempt to regulate its levels.

- Within the European Union, this is laid down in the Basic Safety Standards (BSS). Obligatory for all EU Member States.

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Legislation

Volume 57

17 January 2014

Contents

II *Non-legislative acts*

DIRECTIVES

★ 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, and repealing Directives 89/618/Euratom, 90/641/Euratom, 96/29/Euratom, 97/43/Euratom and 2003/122/Euratom 1

Price: EUR 4

EN

Acts whose titles are printed in light type are those relating to day-to-day management of agricultural matters, and are generally valid for a limited period.

The titles of all other acts are printed in bold type and preceded by an asterisk.

https://eur-lex.europa.eu/eli/dir/2013/59/oj

Legal Basis

- Sets reference level for dwellings and workplaces:300 Bq/m^3

Requires:

- elaboration of Rn Action Plans;
- **identification** of “Rn priority areas”- RPA
- **remediation** of workplaces;
- **prevention** for residential buildings.

Radon Priority Areas

Art. 103,3; Radon Priority Areas (RPA):

"Member States shall identify areas w… annual average) in a signifi… vant nati…

Detect Radon Priority Areas:

There is **not a "fixed" definition**, and different criteria may be applied.

Political decision (and data availability)

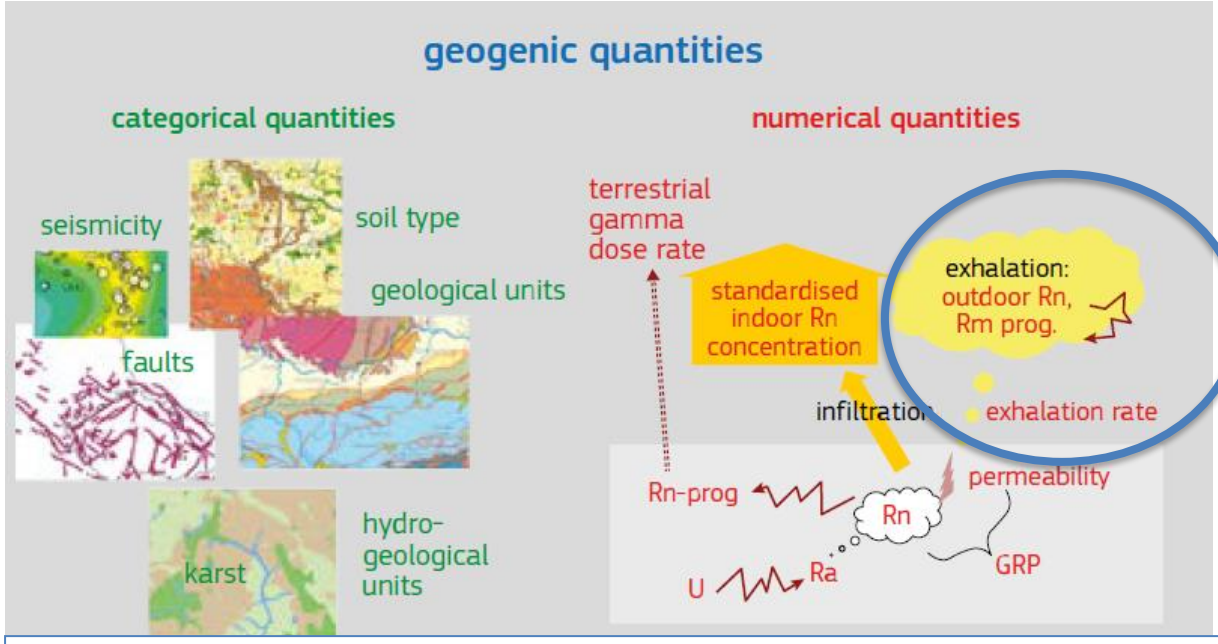
…**rable** definition.

…; Radon Action Plan:

In areas according Art.103,3: Buildings with public access and workplaces must be measured and if above RL, remediated. New buildings: particular Rn prevention. Strategy to reduce Rn in dwellings.

Radon maps: Input Quantities

- Indoor radon
- **geogenic parameters** (radon in soil gas, soil permeability, geology, faults, soil type, Ra-U concentrations in soil/rock, **outdoor radon, radon flux** etc…)



European Commission, Joint Research Centre – Cinelli, G., De Cort, M. & Tollefsen, T. (Eds.), ***European Atlas of Natural Radiation****, Publication Office of the European Union, Luxembourg, 2019.*

RPA_Objective in traceRadon project (task 1)

Develop improved methods for the identification of RPA using outdoor radon activity concentration data, radon flux data and radon flux maps

- ✓ literature review on the use of radon flux data for estimating indoor and outdoor radon activity concentrations as well as the use of the geogenic radon potential

- Čeliković, I. *et al.,* Outdoor Radon as a Tool to Estimate Radon Priority Areas—A Literature Overview. Int. J. Environ. Res. Public Health 2022, 19, 662. https://doi.org/10.3390/ijerph19020662
- Čeliković I., Pantelić G., Vukanaca I., Krneta Nikolić J., Živanović M., Cinelli G., Gruber V., S. Baumann, Ciotoli G., L.S. Quindos Poncela, D.Rabago, 2022. Overview of Radon Flux Characteristics, Measurements, Models and Its Potential Use for the Estimation of Radon Priority. Atmosphere 2022, 13(12), 2005; https://doi.org/10.3390/atmos13122005

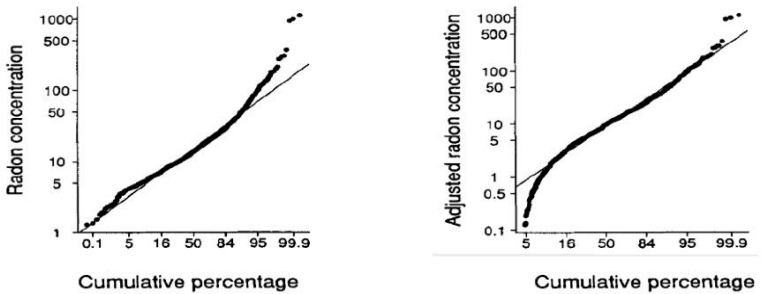
- ✓ test the use of **radon outdoor and radon flux** as input quantities to estimate the GHRI and consequently a tool to estimate the RPA

Literature review: General methodology

- Literature survey included: peer reviewed articles, conference contributions, reports
- Formed (sort of) database in MS Excel consisting of (among else):
  - **Metadata of article**: title, authors, publication date, keywords, abstract, Country...
  - **Indoor radon data**: No.of measurements, measurement method
  - **Outdoor radon data**: No.of measurements, measurement method
  - **Radon flux data**: method used (direct/indirect), if indirect, which model was used; No. of measurement, area covered
  - **Geogenic Radon Potential**: No. of measurements, area covered, uranium/radium concentration, radon in soil gas, permeability, proxy variables, model used
  - **Correlations**: any possible correlations given in the papers
  - Boolean type: Is a Rn map presented in the paper? y/n
  - 2 **subjective categories**: usefullness of the paper and comments
- In total: 389 references used in 2 papers

Literature review: Outdoor radon - motivation

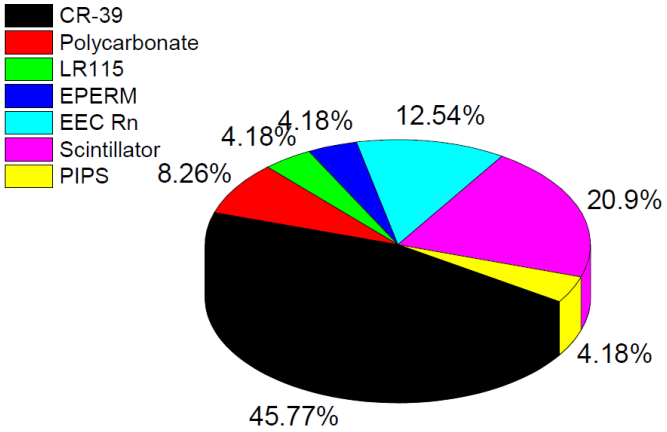
- As a baseline to assess anthropogenic contribution to Rn exposure
- Outdoor radon could contribute to radon dose especially in regions where outdoor radon concentrations are elevated
- Omitting to correct indoor radon for outdoor radon concentrations could lead to an underestimation of percentage of dwellings exceeding a reference level and could have an implication in classification of RPAs



- Correct assessment of radon exposure important for epidemiological studies to detect an effect due to radon

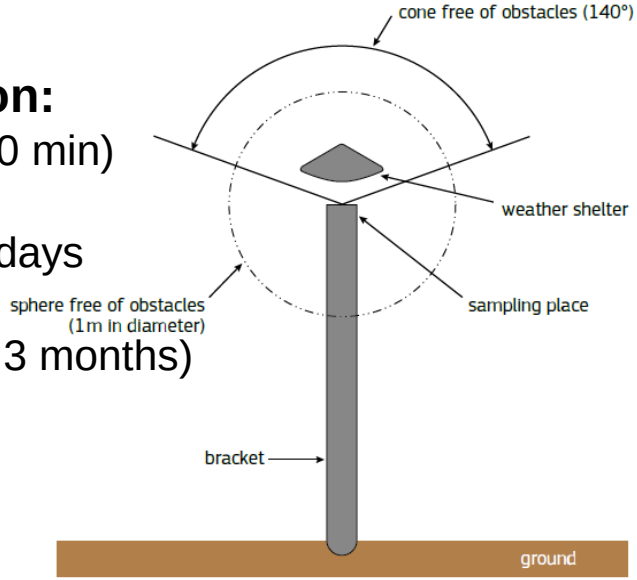
Literature review: Outdoor Rn – measurement method

1. ORC measurement more challenging compared to IRC
2. ORC 1-2 (even more) orders of magnitude lower than IRC
3. Detectors exposed to harsh meteorological conditions and vandalism
4. ISO 11665-1:2012, guidance for measuring ^{222}Rn concentration in the air



Measurement duration:

- instantaneous (10 min)
- A few hours
- A few days – 28 days
- Several months
- Seasonal (3-4 x 3 months)
- A whole year



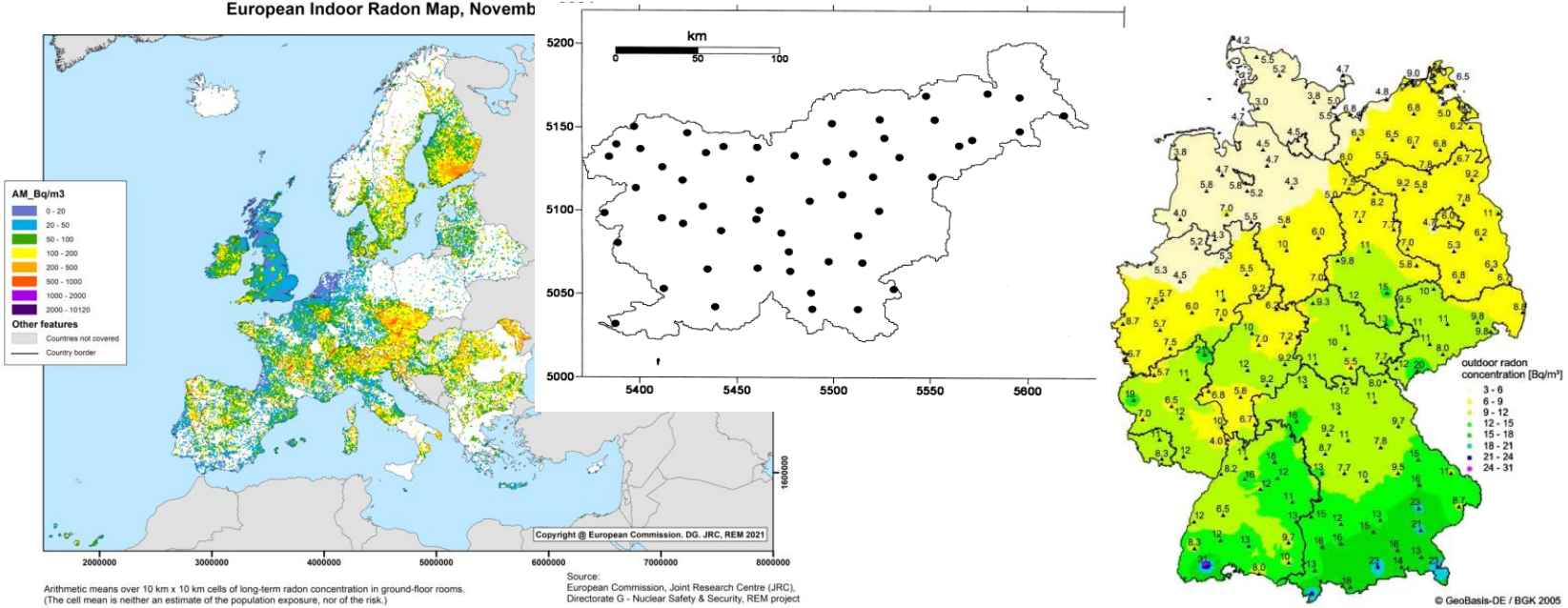
Literature review: Outdoor radon surveys

- Outdoor Rn surveys (max: 696 locations in Japan) VS. Indoor radon surveys (>100000 in UK, >50000 in 5 EU countries)
- Motivations for surveys:
  - to determine anthropogenic contribution (mining industry, repositories…)
  - to link lung cancer patients incidence with radon
  - to investigate influence to IRC,
  - to investigate influence of meteorological parameters…
- Only 5 national outdoor radon surveys worldwide (Germany, Spain, Slovenia, Ireland and Japan)
- **In none of the reviewed articles, an explicit statement that the measurement of radon in air was performed according to the ISO 11665-1:2012 was found**.

Literature review: Outdoor Rn vs Indoor Rn maps

- Only **a few outdoor radon maps** created (Germany: 1 measurement per 50x50 km^2, Slovenia: **1 detector per 20x20 km^2** and 3 maps in USA in Missouri, Iowa and Minnesota with around 40 km distance between measuring locations.)

  VS. Indoor **(**at lest several meas. in 10x10 km^2, up to 1x1 km^2 and 0.5x0.5 km^2)



Literature review: Outdoor radon - Correlations

Country	No. of. locations	Correlation of Outdoor Rn with				
		Indoor air	Soil gas	Exhalation rate	Gamma dose rate	^{226}Ra in soil
USA, Missouri	82	0.11				
USA, Iowa	111	0.2				
Minesota	64	0.7 (for 6 counties)				
Turkey	77	Weak				Weak
Slovenia	60	Good	0.59			
China	101		0.88			
Norway	82				0.64	
Lebanon [1]	24	0.10				
Japan	696				0.62	
East Asia	20			0.79		Weak
Syria[1]	36	0.46	0.16	0.12		0.33

Literature review: Outdoor radon - Conclusions

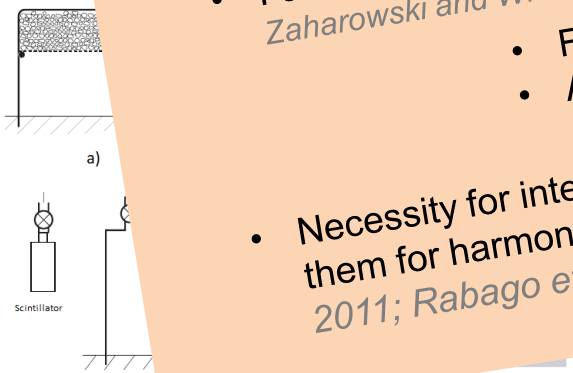
- Large variety of measurement methods and measurement duration
- Outdoor radon measurements should be performed in a more systematic way and at larger scale
- QA/QC given only in a few surveys (mainly duplicate detectors)
- Maps produced on much smaller number of locations over larger grid cells, compared to indoor radon surveys (Could they be considered representative?)
- A few studies calculated correlation factors between ORC and other radon quantities
- A wide range of obtained correlation factors indicates that ORC solely is not enough for IRC prediction, but should be used simultaneously with other influencing factors

Literature review: Rn flux in different disciplines

- In atmospheric studies: i.e. radon tracer method to monitor emissions of different trace gasses
- For estimation of groundwater discharge in a coastal zone
- As a tracer for dynamic processes such as: volcanic activity and earthquake prediction, vicinity of faults
- To measure exhalation of radon from building material
- To plan, monitor and evaluate remediation of uranium mine and mill sites
- To estimate indoor radon concentrations
- To identify areas where radon preventative measures need to be taken during construction, i.e. RPA predictor

Literature review: Rn flux – Measurem ls

- accumulation ch



instantane continuous

- Measurement duration:

- ISO 11665-7:2012 “Accumulation method for estimating surface exhalation rate”

- radon flux measurement are still challenging
- Fast time response need to measure temporal variations of radon flux (Yang et al., 2017; Zaharowski and Whittlestone, 1996; Rabago et al.,2022) :
  - Flow-through method
  - Accumulation method with a fast exchange of air after each accumulation period
- Necessity for intercomparison to identify and quantify possible inconsistencies among them for harmonizing different radon flux measurements and estimations (Grossi et al., 2011; Rabago et al., 2022).

- Prone to different biases:
  - Leakage, back-diffusion,
  - Variation of environmental conditions inside and outside of chamber,
  - Disturbance of soil

Literature review: Rn flux – overview of surveys

- Radon flux regulated in:
  - active uranium mill tailing: 740 mBq m^{-2} s^{-1} *(USA, EPA)*
  - radon flux as an indicator of radon hazard (limit of 80 mBq m^{-2} s^{-1}) at sites prior building a construction *(Russia)*
- Radon flux measurements were performed at a much smaller scale compared to indoor radon surveys (>100000 in UK, >50000 in 5 EU countries)
  - From: 1 location (continuous over whole year)
  - Up to: ~210 locations in Australia (covering several surveys, used for validate a model of *Griffiths et al., 2010*)
  - Japan 111 locations (national survey, ZnS)
- Only 2 national radon flux surveys performed (Japan and Australia)
- Map of measured radon flux created in only a few surveys
- Typically reported: range, mean value, seasonal variations,
  - correlation between measured and estimated Rn flux
  - Correlations with IRC, ^{226}Ra, gamma dose rate…

Literature review: Rn flux correlations

Country	No of Locations	Correlations with Radon Flux				
		^{226}Ra in Soil	Soil Gas	Indoor Air	Gamma Dose Rate	Outdoor Air
Australia	101	0.59			0.54	
Australia		0.58 and 0.22 (for 2 regions)				
China	31	0.748	0.705			
East Asia	20	0.839				0.787
Finland, Hungary					0.66	
France	85			Good		
Greece	6	0.92			0.81	
India	20	0.7		0.5		
Italy	18	0.570[1]				
Italy	12				0.58	
Japan	8	0.69			0.64	
Nigeria	27			−0.32 (wet) −0.30 (dry)		
Romania	20			Figure 4 of [191]		
Russia	12			0.79		
Spain	30			No clear correlation		
Spain	8 locations (3 dwell. per location	No correl. between averaged flux and ^{226}Ra		0.82 (traditional) 0.34 (old) 0.31 (new) dwellings		
Syria [1]	36	−0.05	0.80–0.98 (3 regions)	0.79 (1 region)		
USA	1			See Figures 1 and 3 [139]		

Literature review: Rn flux – conclusions

- More dedicated measurements required to get reliable radon fl
- High correlations between R … een 0.80 and 0.9…
- … radon flux is comparable with time … measurements, which are comparable with temporal … of soil properties
- Both, radon in soil gas and radon flux are quantitie… …ogenic contribution (except near mining …
- … ranging from 0.31 to 0.79, … due to anthropogenic contribution
- … Rn flux measurements: variations smoothed over a long period of time,

short-term Rn flux measurements are suitable for incorporation with GRP mapping and thus estimation of RPA!

long-term Rn flux measurements are more compatible with indoor radon measurements!

Literature review: Radon flux – models

- Already discussed in Presentation of Ute Karstens (Lund) and Arturo Vargas (UPC)

- Therefore, only a few conclusions (from Literature review):
  - Motivation for Rn flux models: A lack of large s… …ata ; A need for accurate input of Rn flux
  - Flux models in a few decad… …mplified models, depending only on latitude, te… …odels

Data suitable for input for GRP mapping and estimation of RPA!

… and temporal resolution reached

…ssary to increase No. of measurements to reduce uncertainty

  - Most models use diffusion as mean of Rn transport, advective transport could be important, especially in the vicinity of faults

Radon outdoor and radon flux / RPA

Test the use of these data to estimate the **Geogenic Hazard Radon Index (GHRI)** and consequently a tool to estimate the RPA

Dedicated presentation tomorrow during the training course!!!!!

Radon outdoor and radon flux / RPA

OBJECTIVE

Can outdoor radon and radon flux improve the prediction of areas with high radon potential?

MAIN STEPS

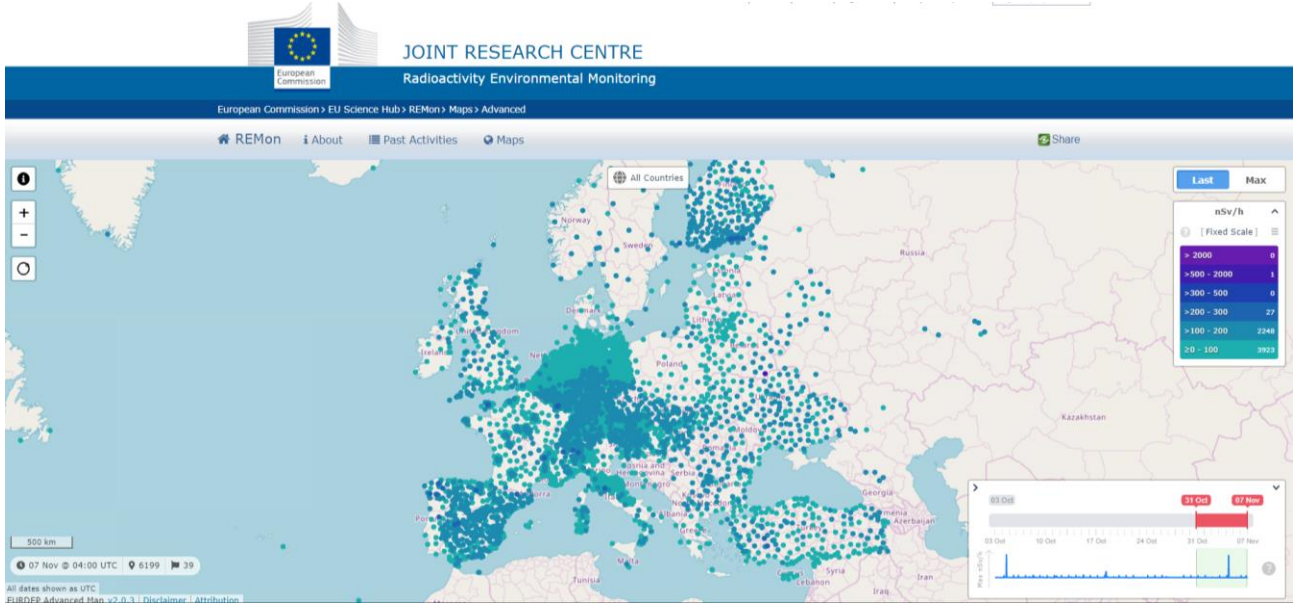
- Data collection
  (Rn flux maps, national outdoor radon data from Germany and Belgium)
- Data analysis
- Methodology (machine learning_ Random forest)
- Preliminary results

Let's continue tomorrow……

Gamma dose rate - GDR

Gamma Dose Rate (GDR) measurements mainly fulfil an early warning or emergency preparedness task in case of a major nuclear and radiological accident with atmospheric release of radioactivity.
Its short sampling and reaction time allow the fastest identification of anomalies.

EURDEP
(EUropean Radiological Data Exchange Platform)



https://remon.jrc.ec.europa.eu/About/Rad-Data-Exchange

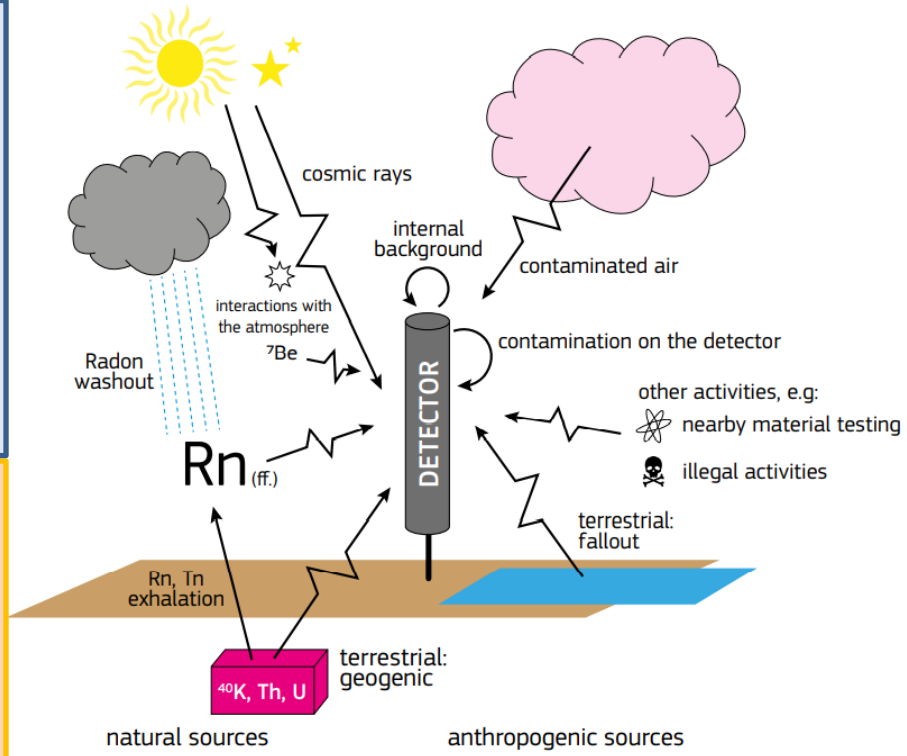
Gamma Dose Rate_components

Constant:

- internal background or self effect of the probe
- cosmic radiation (mainly muons)
- anthropogenic radionuclides (in case of radiological event or accident)
- terrestrial gamma radionuclides (U and Th series, 40K)_TGDR

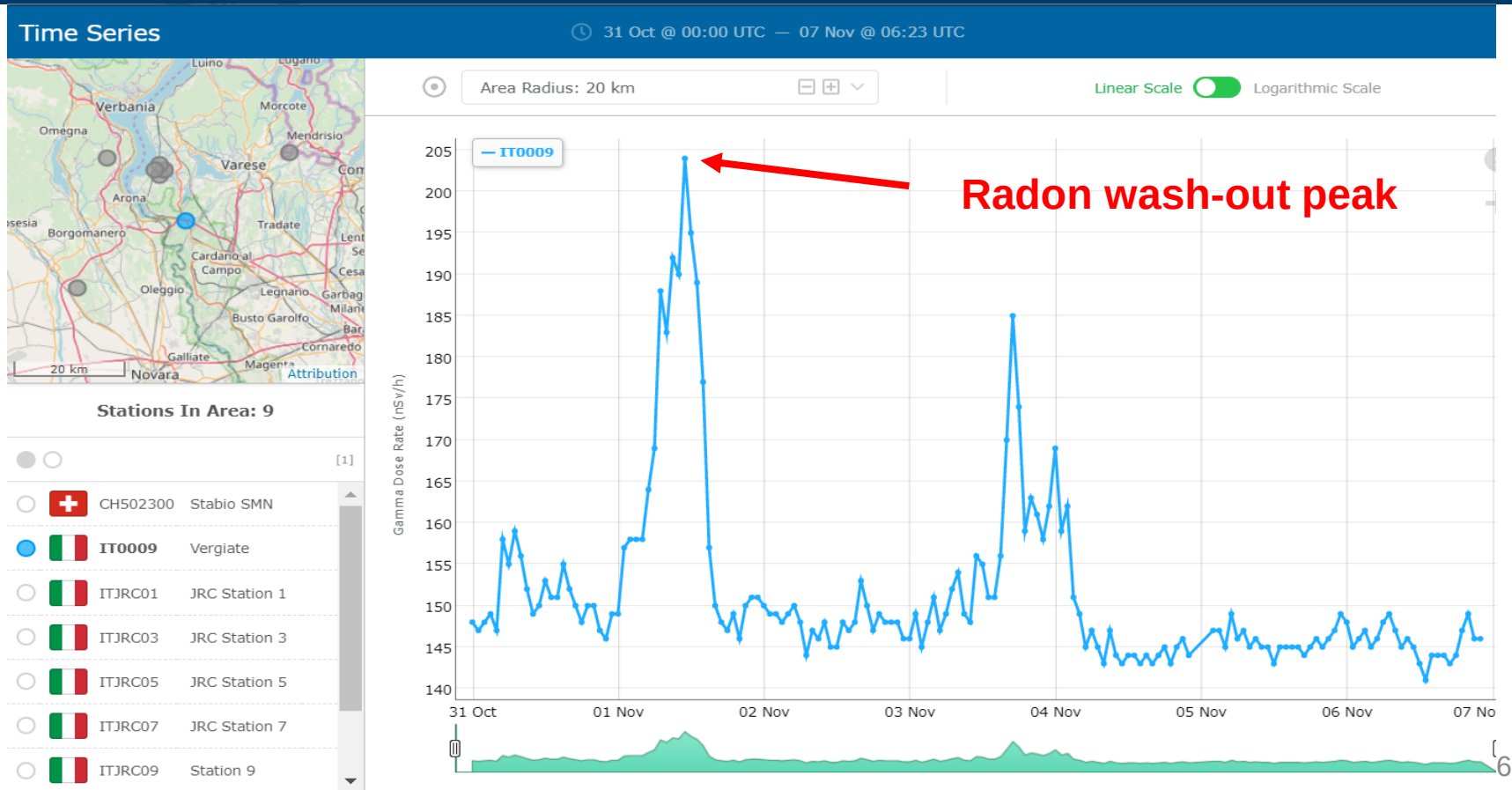
Variable:

- Natural airborne (Rn, Tn and progenies, cosmogenic radionuclides)
- **Wet deposition of Rn progenies *(Radon peak)***
- Fluctuation of TGDR due to different soil humidity
- Rn nocturnal accumulation
- Anthropogenic: Radiological release



European Commission, Joint Research Centre – Cinelli, G., De Cort, M. & Tollefsen, T. (Eds.), ***European Atlas of Natural Radiation****, Publication Office of the European Union, Luxembourg, 2019.*

The identification of the right origin of **GDR peaks** is a crucial issue to prevent the impact of false alarm in the population.



GDR_Objective in traceRadon project (task 2)

Develop methods for estimating radon wash-out peaks from total gamma dose rate data measured in the EURDEP early warning system

- ✓ Identify and characterise GDR peaks
- ✓ Study correlation between ADER peaks, meteorological parameters and Rn progenies concentration (using outdoor radon and radon flux data)

✓ Identify and characterise GDR peaks

First comparison analysis of the peak identification and classification methods in the framework of traceRadon (WP4) and EURADOS* WG3-S1

*The European Radiation Dosimetry Group (EURADOS) is a network of 80 European institutions (Voting Members) and more than 600 scientists (Associate Members).

Participants

Claudia Grossi, UPC
Susana Barbosa, INESC TEC
Alessandro Rizzo, ENEA
Miguel Hernandez, UCO
Peter Bossew, BfS*
Ulrich Stöhlker, BfS*

*retired

1st round

Time series of Ambiet Dose Equivalent Rate, H*(10)(nSv/h)

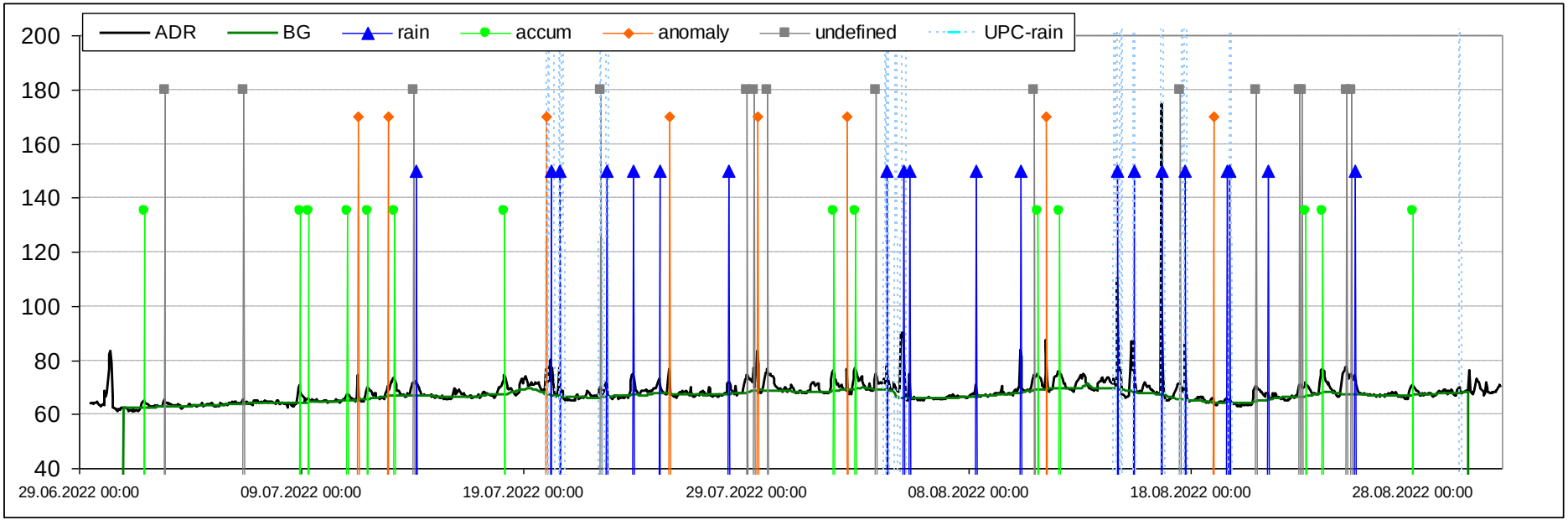
1 hour resolution

2nd round

Rain data,

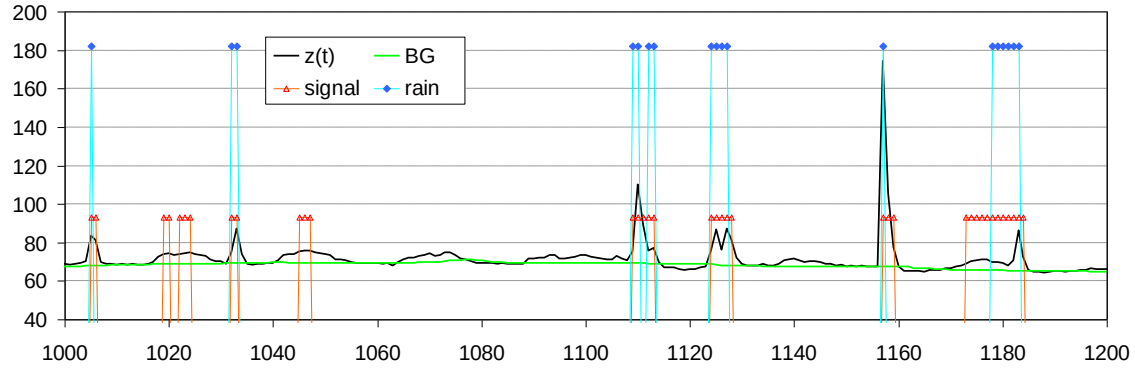
1 and 10 min resolution

Example: peaks identified after 2nd round

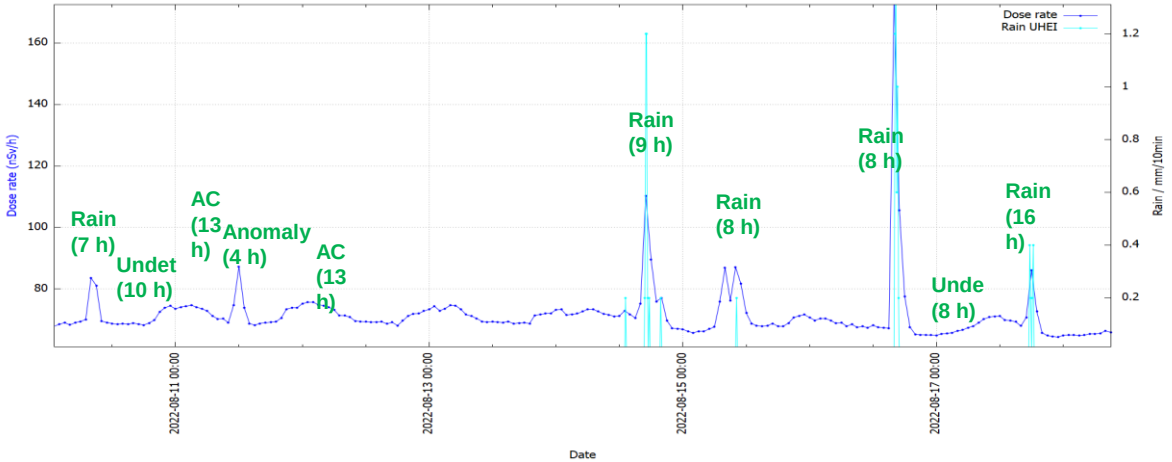


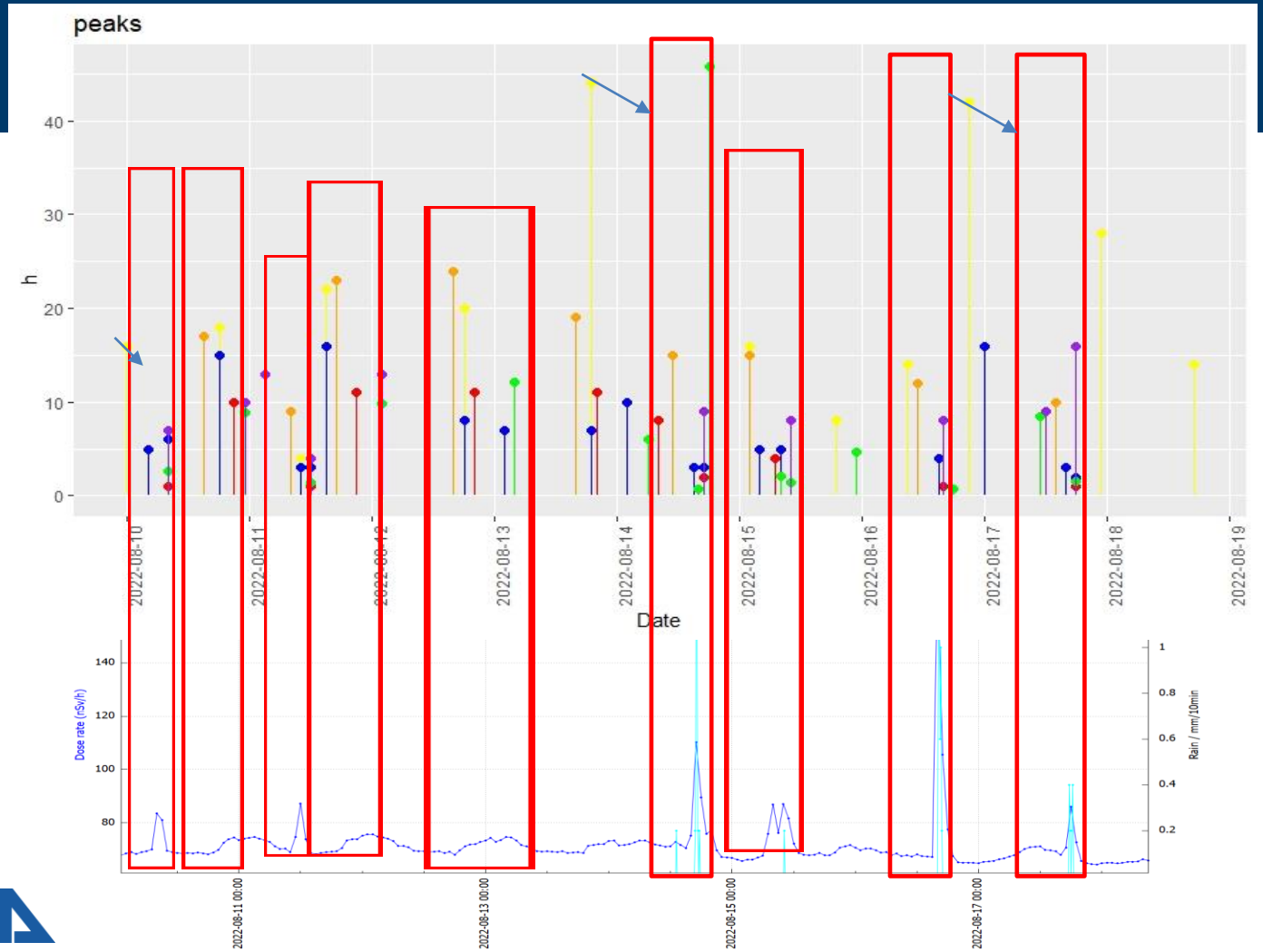
Example, short period (8 days)

1st round



2nd round




peaks
h
40
30
20
10
0
2022-08-10
2022-08-11
2022-08-12
2022-08-13
2022-08-14
2022-08-15
2022-08-16
2022-08-17
2022-08-18
2022-08-19
Date
Dose rate (nSv/h)
140
120
100
80
Rain / mm/10min
1
0.8
0.6
0.4
0.2
2022-08-11 00:00
2022-08-13 00:00
2022-08-15 00:00
2022-08-17 00:00

Preliminary conclusions

- Sensitivities for peak identification are different for each code;
- Time duration varies between participants;
- Nocturnal accumulation are considered by all participants;
- Rain data are fundamental to optimize – correct classification of peaks

Report and paper to summarize the results ON GOING!

Thanks, Danke, Grazie

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