



Literature survey on use of outdoor radon concentrations for estimation of radon priority areas



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Framework of literature survey on outdoor Rn

- EC Directive 2013/59/ Euroatom Article 103 :

Identification of RPA: “Member States shall identify areas where the radon concentration (as an annual average) in a significant number of buildings is expected to exceed the relevant national reference level.”

- Delineation of RPA:

- Indoor radon concentration
- Geogenic radon potential

- Different mapping methods (include different parameters):

- **measured quantities** such as: indoor radon concentrations, radon in soil gas, permeability, radionuclide content in soil, TGDR
- **geological data:** type of soil, hydrology and faults;
- **meteorological data:** precipitation, pressure
- **anthropogenic factors:** building characteristics, living habits

One can notice that the data on outdoor radon and radon flux were generally missing for delineation of RPA

traceRadon:

- EMPIR 19ENV01 “Radon metrology for use in climate change observation and radiation protection at the environmental level”
 - WP1: aims to develop traceable methods for the measurement of outdoor low-level radon activity concentrations in the range of 1 to 100 Bqm⁻³ with uncertainties of 10% (k = 1)
 - WP2 aims to improve the accuracy of radon flux measurements for the purpose of: (1) identifying Radon Priority Areas (RPAs) for radiation protection goals; and (2) retrieving indirect GHG fluxes using the RTM.
 - WP3 aims to validate current radon flux models and inventories using traceable measurements of radon flux and radon activity concentration supported by dosimetric and spectrometric data from the radiological early warning networks
- **WP4 will provide dynamic outdoor radon concentration and radon flux maps for climate change research and radiation protection.**


Task 4.1: To develop improved methods for the identification of RPA using outdoor Rn activity concentration data, Rn flux data and Rn flux maps.

Task 4.2 To develop improved methods for estimating radon wash-out peaks from total gamma dose rate data in the EURDEP early warning system

Task 4.3 To provide online easily usable dynamic radon activity concentration and radon flux maps for climate change research and radiation protection

Task of literature review:


A.2.3.2, A.2.3.3, A.2.3.4
A.3.1.4, A.3.2.6



A. 4.1.2 **JRC**, AGES, UC, VINS
to identify the best input data to be
used as an estimate for IRC

- outdoor radon concentration


A.2.3.2, A.2.3.3, A.2.3.4
A.3.1.4, A.3.2.7



A. 4.1.3 **UC**, AGES, JRC, VINS
correlation of these data

- radon flux measurements


A.2.3.2, A.2.3.3, A.2.3.4
A.3.1.4, A.3.2.6



A.4.1.4 **AGES**, VINS, UC, JRC
estimation of the geogenic RHI

- radon flux maps

A.4.1.2, A.4.1.3
A.4.1.4



A. 4.1.5 **AGES**, UC, JRC, VINS
which data is the best for use in
improving the identification of RPA

Literature survey – overview:

- More than 100 references
- Published paper on literature overview on outdoor
(*Celikovic et al., IJERPH 19(2) 2022, 662*; <https://doi.org/10.3390/ijerph19020662>)
- Prepared paper on use of Rn flux for RPA estimation

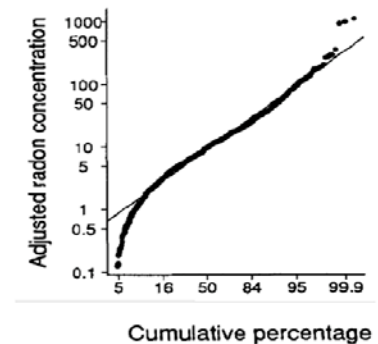
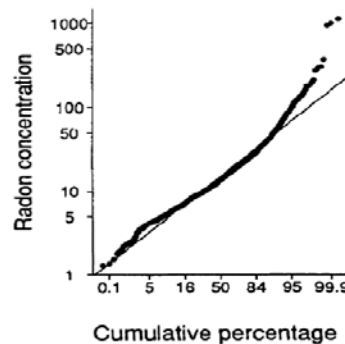
- The use of radon in many scientific disciplines:
 - as a tracer gas for estimation of greenhouse gases
 - to investigate mixing processes in the atmospheric boundary layer and evolution of air pollution
 - as a tracer for dynamic processes such as: volcanic activity and earthquake prediction...
 - ...

- **to estimate the health risk due to exposure to radon and its progeny**

Motivation for outdoor radon measurements:

- 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 (Niška Banja, Serbia: outdoor Rn : max: 168 Bq m⁻³, Ullensvang commune, Norway: max. 114 Bq m⁻³)

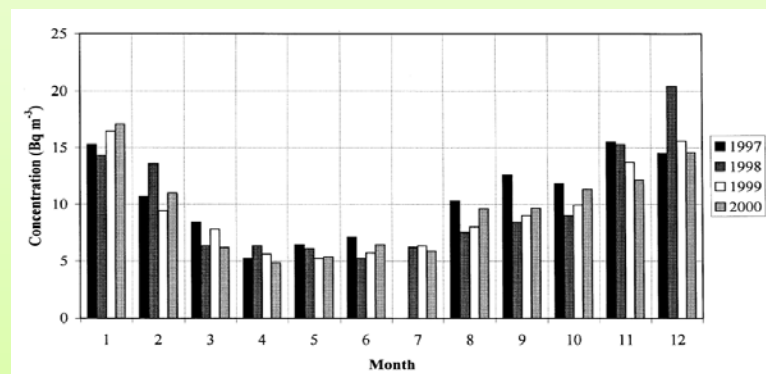
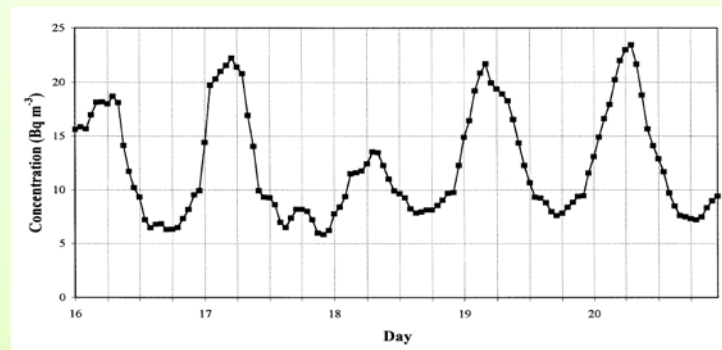
- Omitting to correct indoor radon for outdoor radon concentrations could lead to an underestimation of percentage of dwellings exceeding a ref. level and could have an implication in classification of RPAs



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

Properties of outdoor radon:

- Parameters influencing variations of outdoor Rn:
 - Source
 - Transport and exhalation
 - Dispersion processes
- Diurnal variations
- Seasonal variations
- Annual variations
- Spatial variability

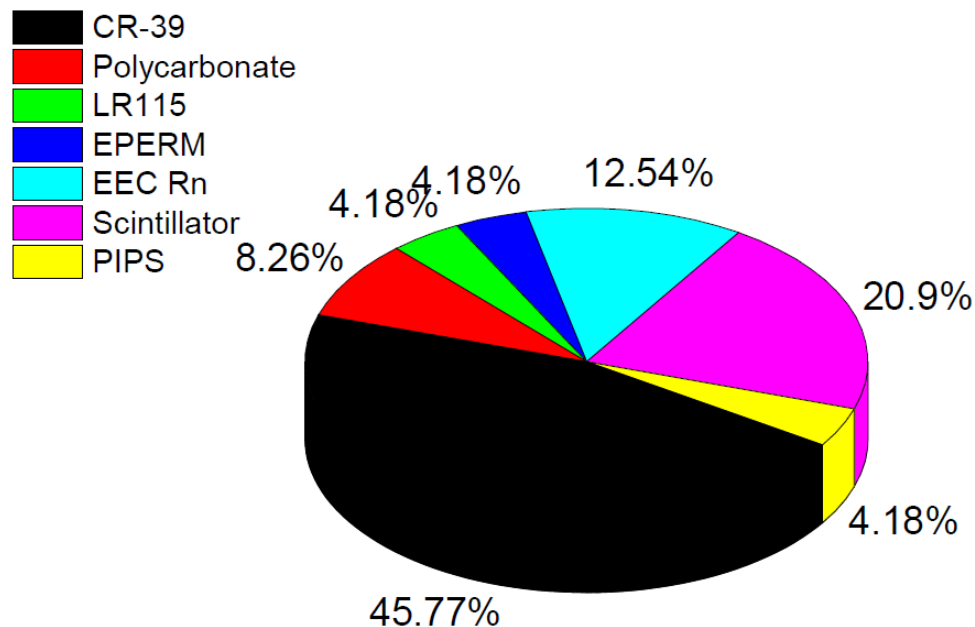


Sesana et al., 2003

Measurement methods:

(from the health risk point of view)

- ORC measurement more challenged compared to IRC
- ORC 1-2 (even more) orders of magnitude lower than IRC
- Detectors exposed to harsh meteorological conditions



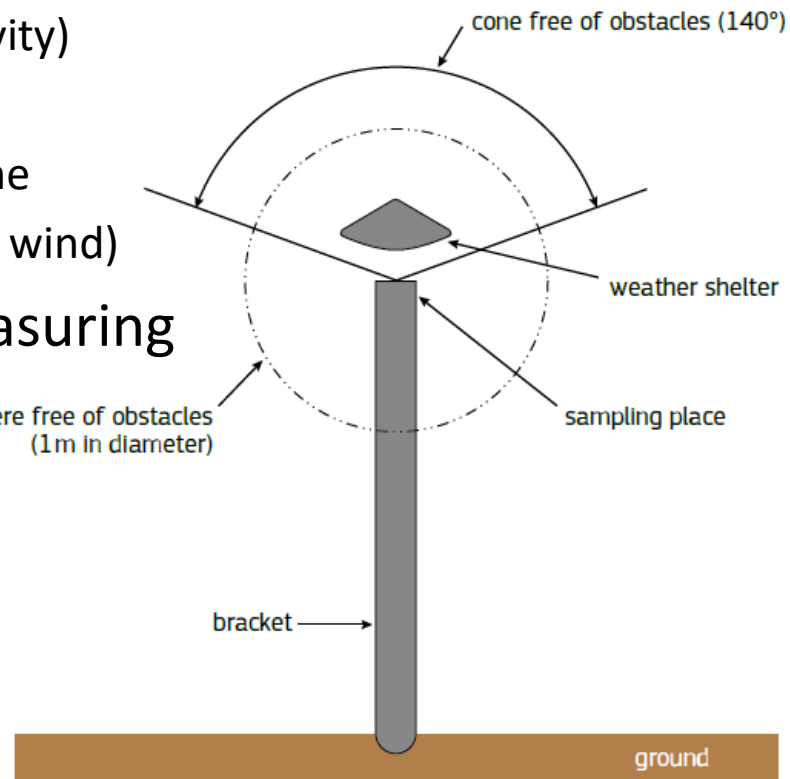
Measurement duration:

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

Measurement methods:

- A special attention was paid to the reduction of the background of detectors, increase of the measurement precision and sensitivity:
 - Pre-etching (to distinguish Rn tracks from the background)
 - Selection of detectors with the lowest possible background
 - Two detectors per location (increase sensitivity)
 - Detector manipulation (storing and mailing)
 - Special design of containers to counteract the effects of outdoor environment (Sun, humidity, wind)
- ISO 11665-1:2012, guidance for measuring ^{222}Rn activity concentration in the air

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.



Outdoor radon surveys:

- Anthropogenic contribution
 - Potentially high ORC (e.g.: 5-1700 Bqm⁻³ German survey)
 - Typically could not be detected at distances > 1 km
 - Topological and climatological characteristics of the area can prevent radon from its immediate dispersion (e.g. U-mine, Zirovski vrh, Slovenia)
 - influence of phosphogypsum repository on ORC in nearby Huelva city, Spain

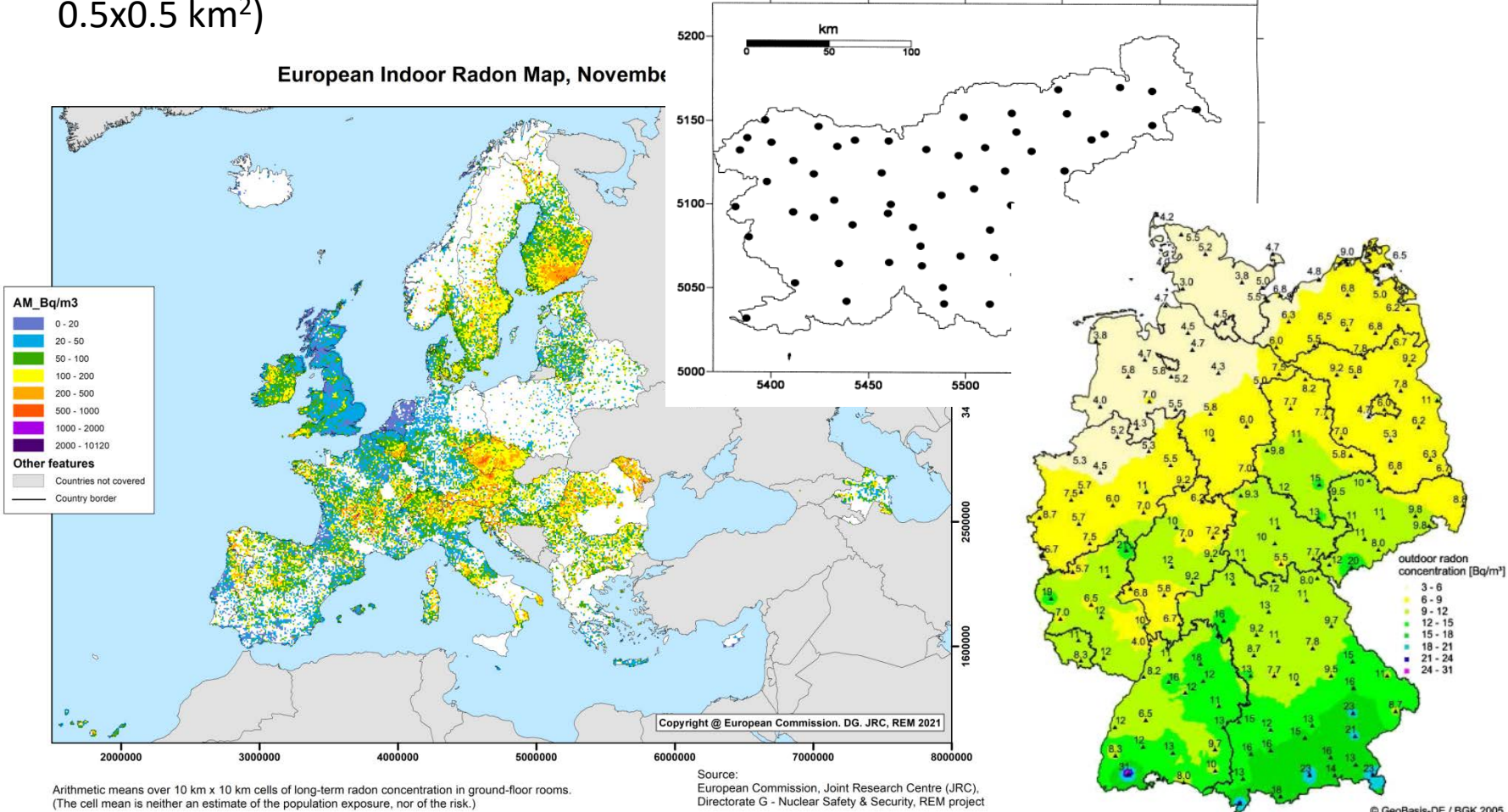
ORC should be monitored (determined) in industrial complexes that produce Ra/U rich waste. Especially, when close to settlements and/or situated at specific terrain configuration that prevents immediate radon dispersion

Outdoor radon surveys:

- Outdoor radon surveys were performed at a much smaller scale compared to indoor radon surveys
(max: 696 locations in Japan **VS.** >100000 in UK, >50000 in 5 EU countries)
- Motivations:
 - to determine anthropogenic contribution,
 - to link lung cancer patients with radon
 - to determine radon background level,
 - to investigate influence to IRC,
 - to investigate influence of rapid industrial development,
 - to investigate influence of meteorological parameters...
- Only a few national outdoor radon surveys worldwide
(Germany, Slovenia, Ireland and Japan)

Outdoor radon surveys:

- Only a few outdoor radon maps created (Germany: 1 measurement per 50x50 km², Slovenia: 1 detector per 20x20 km² and 3 maps in USA in Missouri, Iowa and Minnesota with around 40 km distance between measuring locations.) **VS. Indoor** (at least several meas. in 10x10 km², up to 1x1 km² and 0.5x0.5 km²)



Correlation of outdoor radon with other radon quantities

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

Final remarks

- Strong motivation to measure outdoor Rn concentrations;
- 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

Thank you for your attention