MetroRADON Intercomparison of indoor radon measurements under field conditions

Carlos Sainz

Daniel Rábago, Santiago Celaya, Enrique Fernández, Luis Quindós, Jorge Quindós, Alicia Fernández, Ismael Fuente, Luis Santiago Quindós.

Radon Group, University of Cantabria, Spain

Laruc laboratory

Introduction

★ Completed

★ **A3.3.1 – UC (First intercomparison call)**

Document with a brief intercomparison description

★ **A3.3.2 – UC-JRC (Participants Selection)**

It was stablished a maximum number of participants: **20**

Radon in air (Passive and Actives): Laboratory of Natural Radiation (LNR)

Radon Exhalation and Soil gas measurements: LNR outdoor areas

★ **A.3.3.3 – UC-JRC (Intercomparison Activity)**

Carried out on 5th – 8th November 2018

★ **A.3.3.4 – UC-JRC (Results Analysis)**

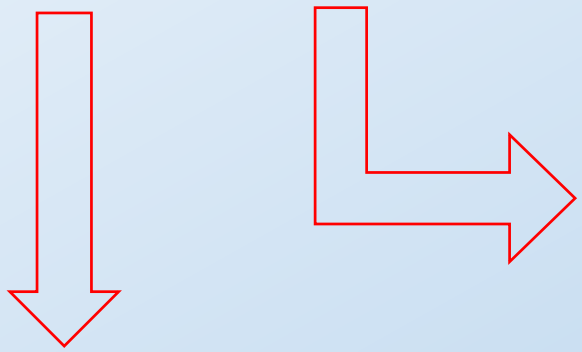
Create a Report ★ and a Paper ★

Introduction

★ **A.3.3.4 – UC-JRC (Results Analysis)**

★ Completed

Create a Report ★ and a Paper ★



- Submitted to a journal (Jan 2020):

***International Journal of Environmental Research and Public Health* (IJERPH)**

- **Completed in February 2019**

Uploaded to MetroRADON web page

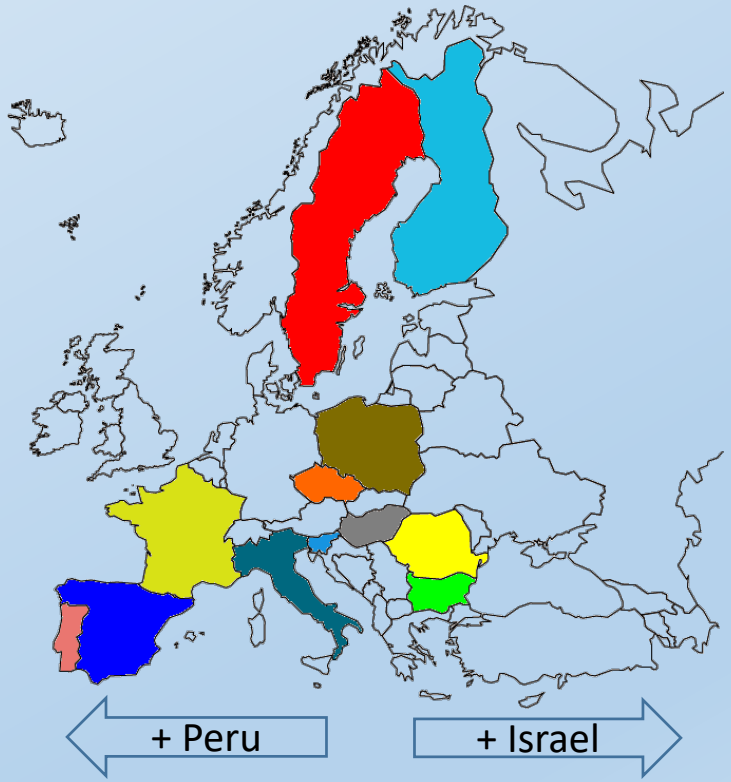
⇨ **Documents\Reports & Journal Publications**

http://metroradon.eu/wp-content/uploads/2019/05/Report_WP3_3_3_MetroRADON_Intercomparison_final-1.pdf

Introduction

Maximum participants number was reached: 20

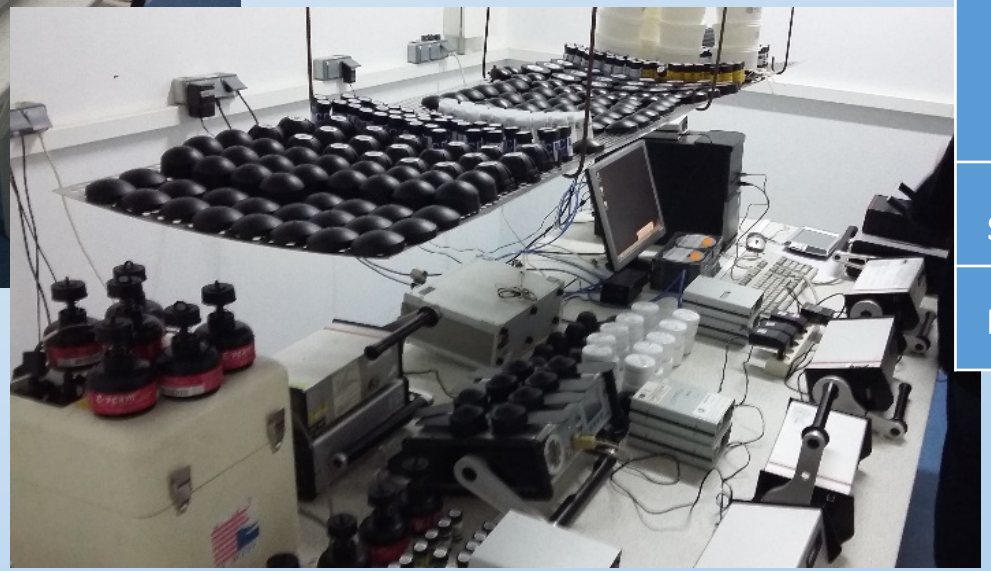
Activity	Participant number	No. of Results
Rn in Air (Passive)	19	23
Rn in Air (Active)	8	22
Rn in soil	5	5
Exhalation	3	3



List of Participants

Acronym	Institution	Country
CIEMAT	Centro de investigaciones energéticas, medioambientales y tecnológicas	Spain
CLOR	Central Laboratory for Radiological Protection	Poland
ENEA	ENEA Radon Service	Italy
INAIL	Italian National Institute for Insurance against Accidents at work	Italy
IRSN	Institut de Radioprotection et de Sûreté Nucléaire	France
JRC	Joint Research Centre	Italy
LaRUC (UC)	Laboratory of environmental radioactivity, University of Cantabria	Spain
LRAB - UEX	LRAB - Universidad de Extremadura	Spain
LRG	Laboratorio de Radón de Galicia	Spain
LRN-UC	Laboratorio de Radioatividade Natural - Universidade de Coimbra	Portugal
NRCN	Nuclear Research Center Negev	Israel
PUCP	Pontificia Universidad Católica Del Perú	Peru
RADONOVA	Radonova Laboratories AB	Sweden
Radosys	Radosys / Radosys Atlantic	Portugal/Hungary
RERA-CIEMAT	Centro de investigaciones energéticas, medioambientales y tecnológicas	Spain
STUK	Radiation and Nuclear Safety Authority	Finland
SUBG	Sofia University "St. Kliment Ohridski"	Bulgaria
SUJCHBO	National Institut for NBC Protection	Czech Republic
TR	TECNO RAD s.u.r.l.	Italy
UBB	Babes-Bolyai University	Romania

Monitor	Detection technology	Sensitivity (cpm at 1 kBq m^{-3})
AlphaGUARD	Ionisation chamber	50
ATMOS12 DPX	Ionisation chamber	20
SARAD EQF 3120	Silicon detector	7
Radon Scout	Silicon detector	1.8
Radon Scout Home	PIN photo diode	0.1

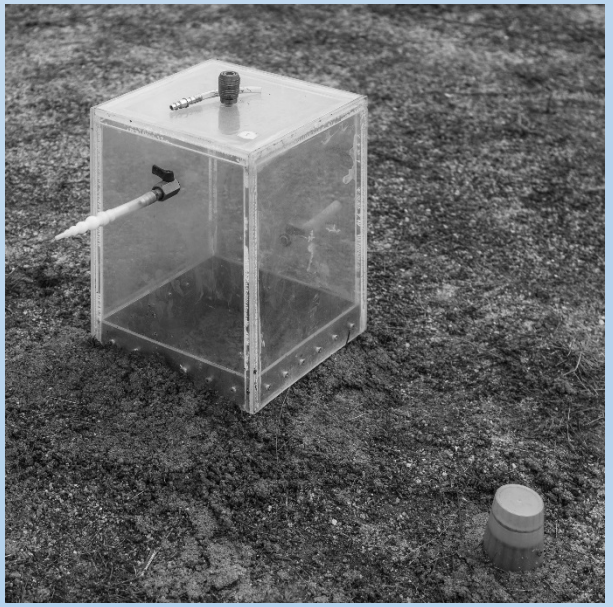


Detector	Diffusion chamber
CR-39 RSKS 100 mm^2 (Radosys)	Diameter 26 mm, height 55 mm 29 cm^3 volume
CR-39 24.7×36.7×1.40 (mm) (Mi-Net)	ENEA patent
CR-39 Radout 25×25×1.5 (mm) (Mi.am)	Diameter 50 mm, height 20 mm
CR-39 TASTRAK 13×37×1 (mm) (Tasl)	Diameter 58 mm, height 20 mm NRPB/SSI
CR-39 Duotrack (Radonova)	Diameter 58 mm, height 40 mm
CR-39 Radtrak2 (Radonova)	Diameter 58 mm, height 20 mm NRPB/SSI
CR-39 Rapidos (Radonova)	Diameter 58 mm, height 40 mm
ST Electret Teflon (E-PERM)	L-OO Chamber 58 mL
ST Electret Teflon (E-PERM)	S Chamber 210 mL
LR-115 type2 400 mm^2 (DOSIRAD)	Diameter 60.4 mm, height 27.6 mm Own design
LR-115 (KODAK) RAMARN device 0.012 mm film of cellulose nitrate, and coated on 0.1 mm thick polyester base	Polypropylene chamber 700 cm^3 volume
Makrofol 75.7 mm^2 STUK design “Radonpurkki”	Diameter 20 mm, height 71 mm 79 cm^3 volume
DVD half made of polycarbonate and two thin Makrofol N foils	Thin CD case

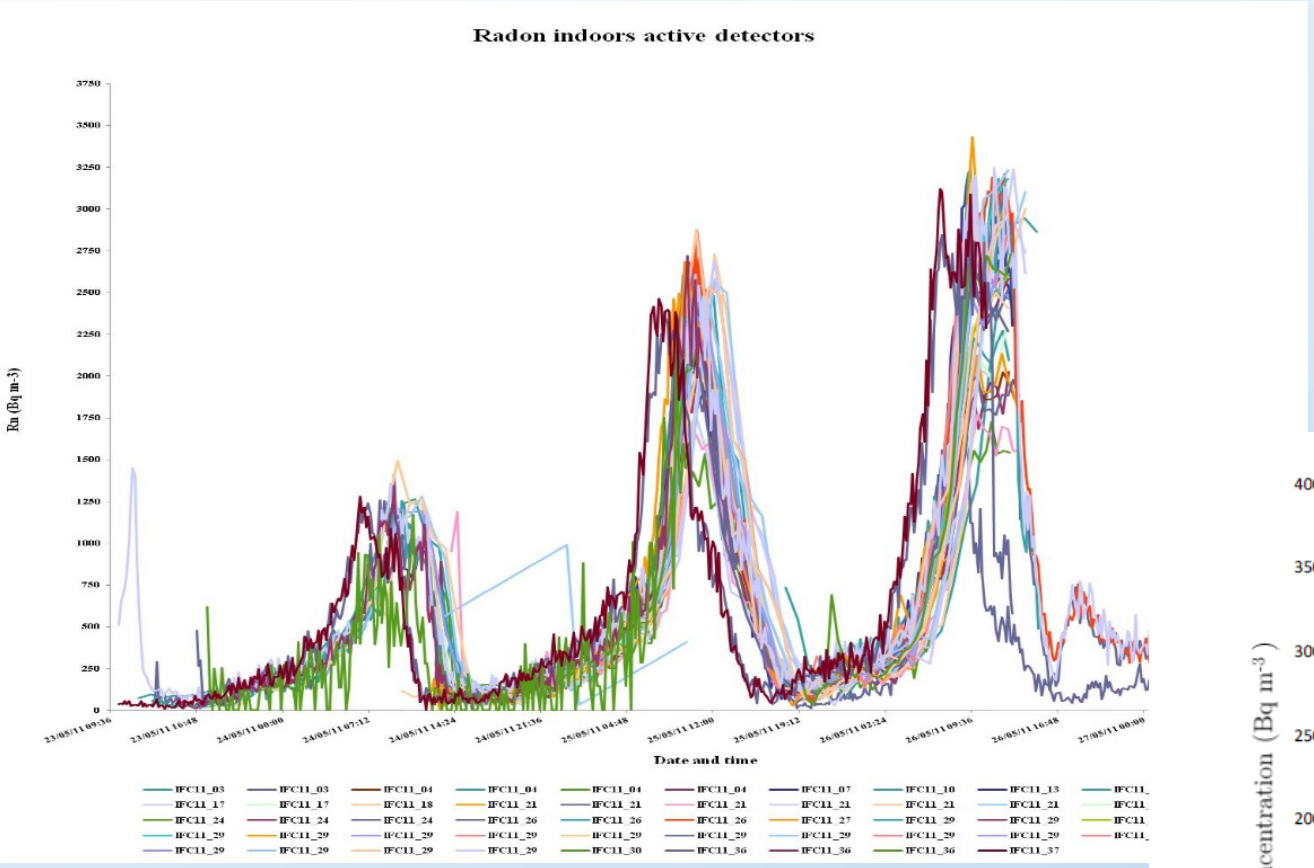
Site description

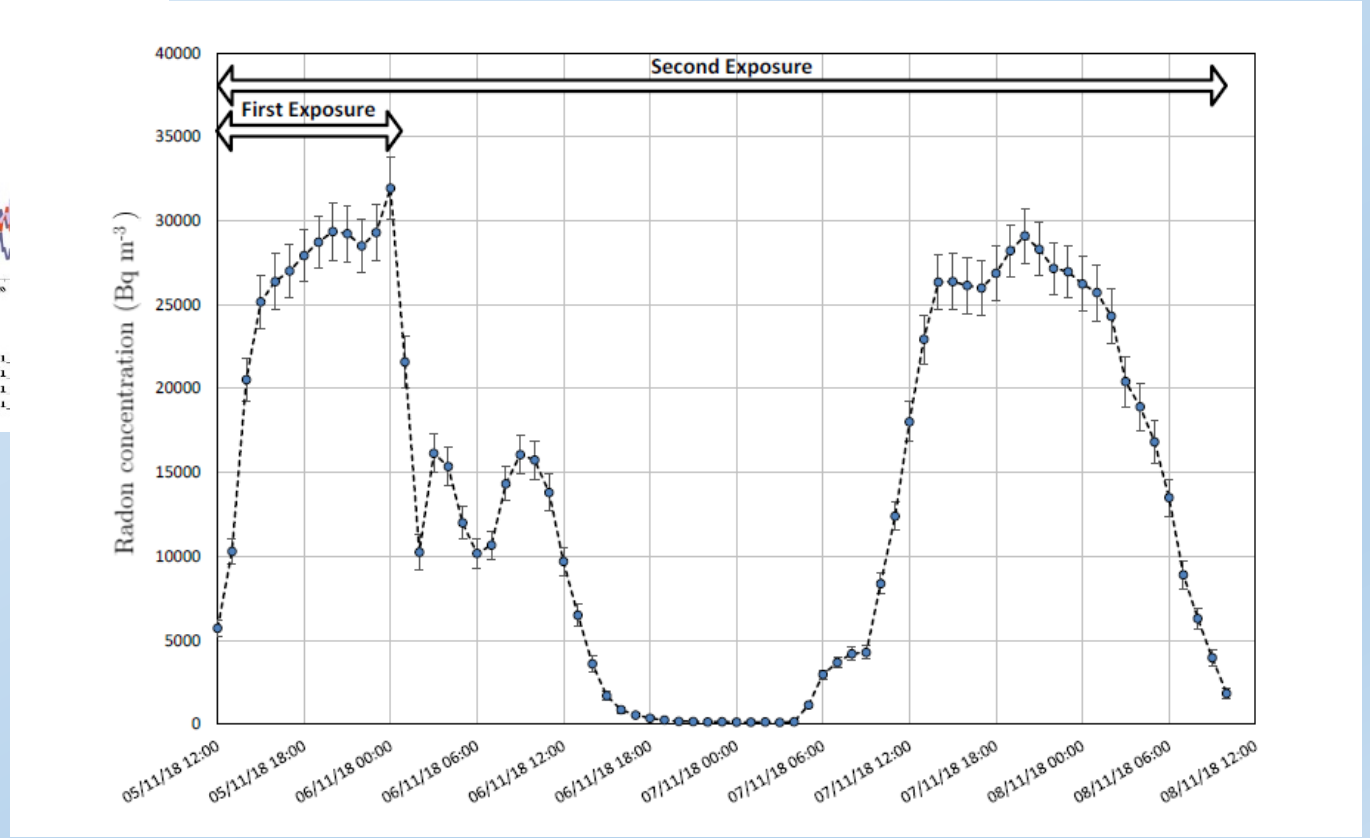
LABORATORY OF NATURAL RADIATION

(SAELICES EL CHICO, SALAMANCA, SPAIN)



Pictures: Hynek, 2018

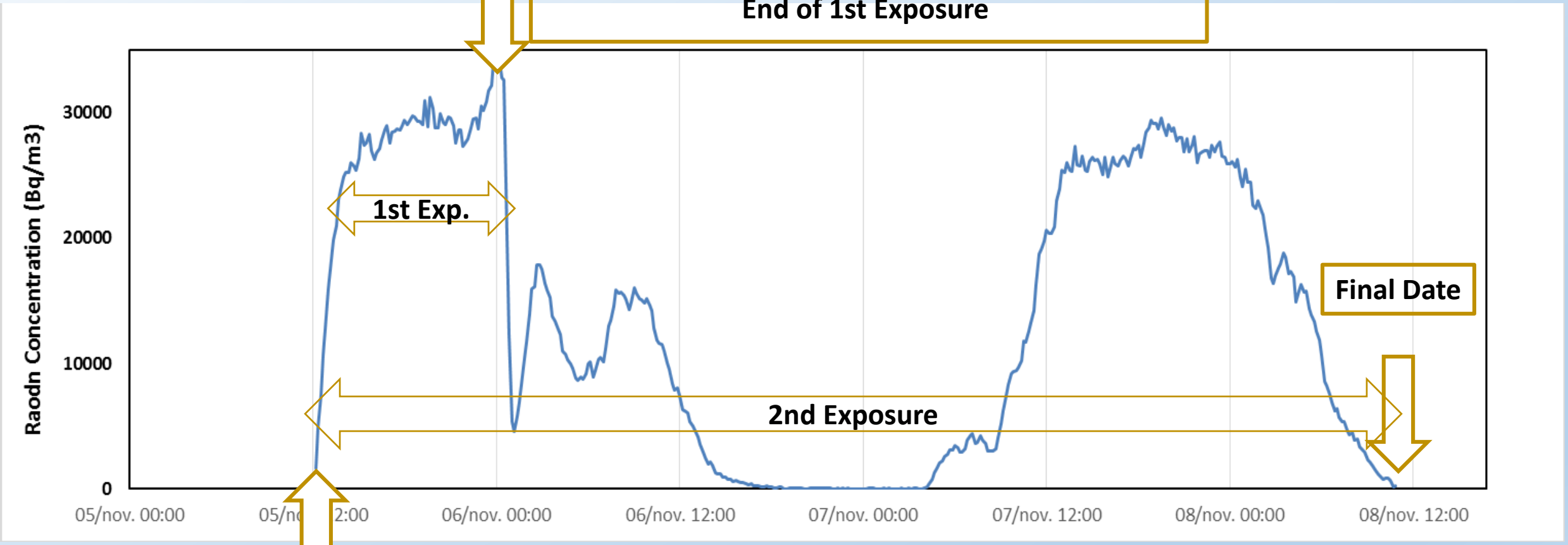




- **The Laboratory of Natural Radiation (LNR) –** A place to test radon instruments under variable conditions of radon concentration and climatic variables Nukleonika **2016**; 61 (3): 275-280.
- 4 **International Intercomparisons**
- 2 **Training Courses** sponsored by **IAEA**, Radon for building professionals, **2017 and 2018**

EXPOSURE CONDITIONS

1:00 a.m in the night: First detectors group retired
End of 1st Exposure



	Start date	End date
1st exposure E1:	05/11/2018 12:00	06/11/2018 1:00
2nd exposure E2:	05/11/2018 12:00	08/11/2018 10:00

Data analysis

Reference Values obtained from consensus value ISO 13528:2015.

There are p items of results denoted as:

$E_i = E_1 , E_2 , E_3, \dots , E_p$

Calculate initial values for E_{ref} and s^* as:

E_{ref} = median of E_i

$s^* = 1.485$ median of $|E_i - E_{ref}|$

Update the values of E_{ref} and s^* as follows. Calculate:

$\delta = 1.5\, s^*$

$$E_i^* = \begin{cases} E_{ref} - \delta & \text{when} \quad E_i < E_{ref} - \delta \\ E_{ref} + \delta & \text{when} \quad E_i > E_{ref} + \delta \\ E_i & \text{otherwise} \end{cases}$$

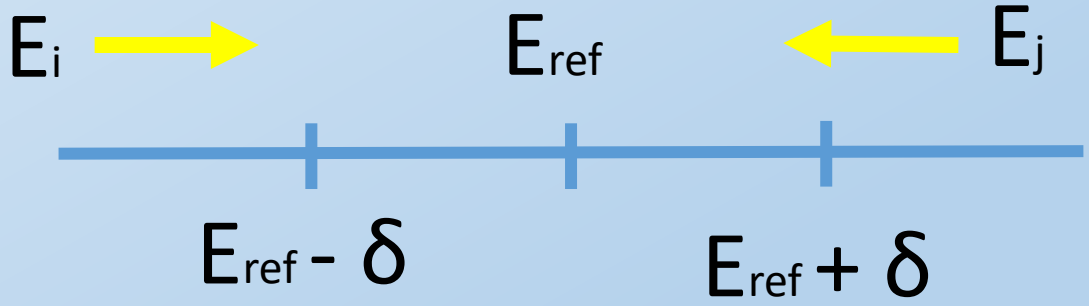
Calculate the new values of E_{ref} and s^* from:

E_{ref} = mean of E_i^*

s^*= 1.134·SD (E_i^*)

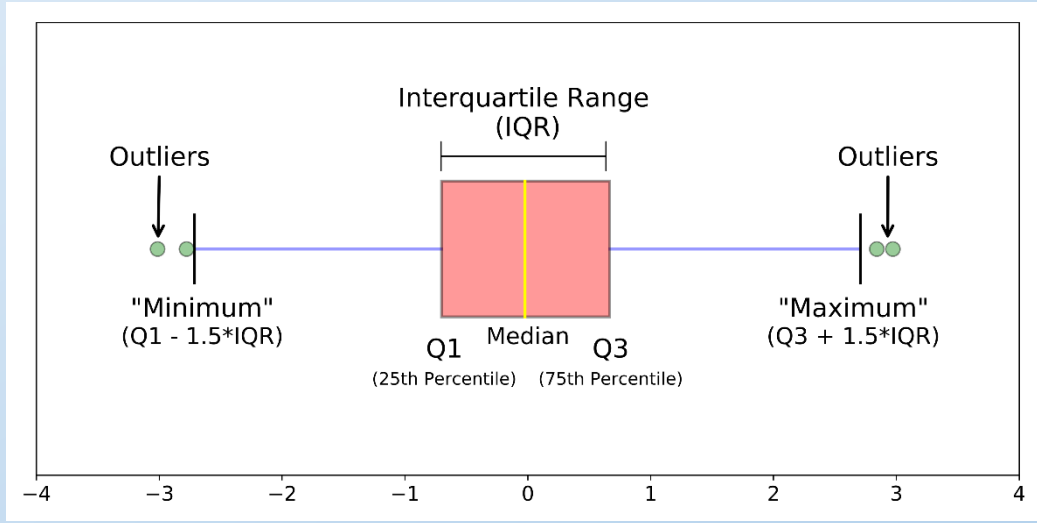
The robust estimates E_{ref} and $s^*$are derived by an iterative calculation, i.e. by updating the values of E_{ref} and s^* several times until the process converges.

ITERATIVE PROCESS

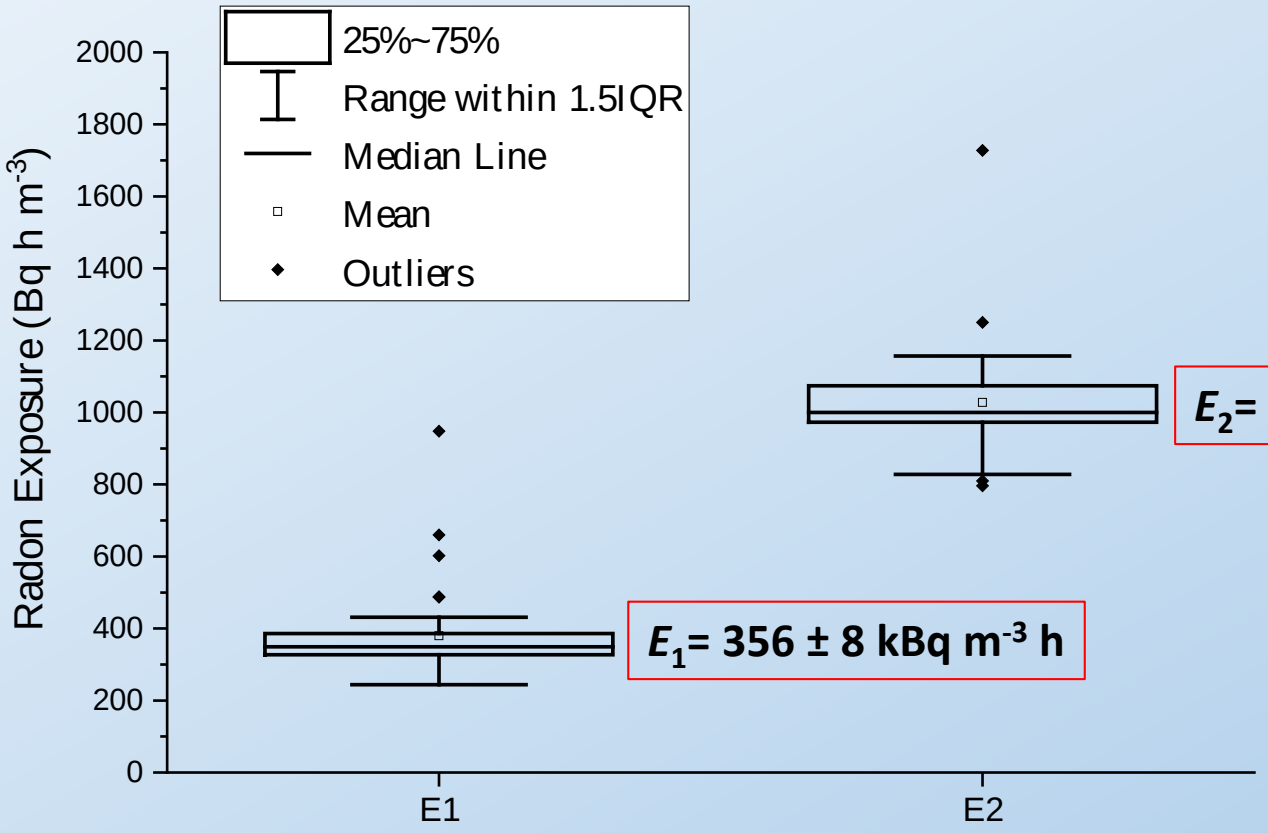


$$u(E_{ref}) = 1.25 \frac{s^*}{\sqrt{p}}$$

Data analysis



https://www.towardsdatascience.com/



E_2= 1014 ± 13 kBq m^{-3} h

E_1= 356 ± 8 kBq m^{-3} h

Data analysis - Metrics

Relative Difference

$$D_i(\%) = 100 \cdot \frac{E_i - E_{ref}}{E_{ref}}$$

Zeta Score

$$\zeta_i = \frac{E_i - E_{ref}}{\sqrt{u^2(E_i) + u^2(E_{ref})}}$$

z-score

$$z_i = \frac{E_i - E_{ref}}{\sigma_p}$$

E_{ref}: Reference value

$u(E_{ref})$: uncertainty of reference value

E_i: Exposure of each participant

***u(Ei):* Participant exposure uncertainty**

σ_p: Standard deviation for the intercomparison assessment

20% for the first exposure

10% for the second exposure

Data analysis - Metrics

$$D_i(\%) = 100 \cdot \frac{E_i - E_{ref}}{E_{ref}}$$

$$\zeta_i = \frac{E_i - E_{ref}}{\sqrt{u^2(E_i) + u^2(E_{ref})}}$$

$$z_i = \frac{E_i - E_{ref}}{\sigma_p}$$

| ζ |; | z | ≤ 2.0 result is considered satisfactory

2.0 < | ζ |; | z | < 3.0 result is considered to give a problem

| ζ |; | z | ≥ 3.0 is considered not satisfactory

ζ score	z-score	Action to take
Satisfactory	Satisfactory	Participant's result is good. No action is required.
Not satisfactory	Satisfactory	Participant's claimed uncertainty is too low, but the result fulfils the intercomparison requirements.
Satisfactory	Not Satisfactory	Participant's uncertainty assessment is accurate but the results do not fulfil the intercomparison requirements.
Not Satisfactory	Not Satisfactory	Participant's result is biased in excess. A complete revaluation should be performed.

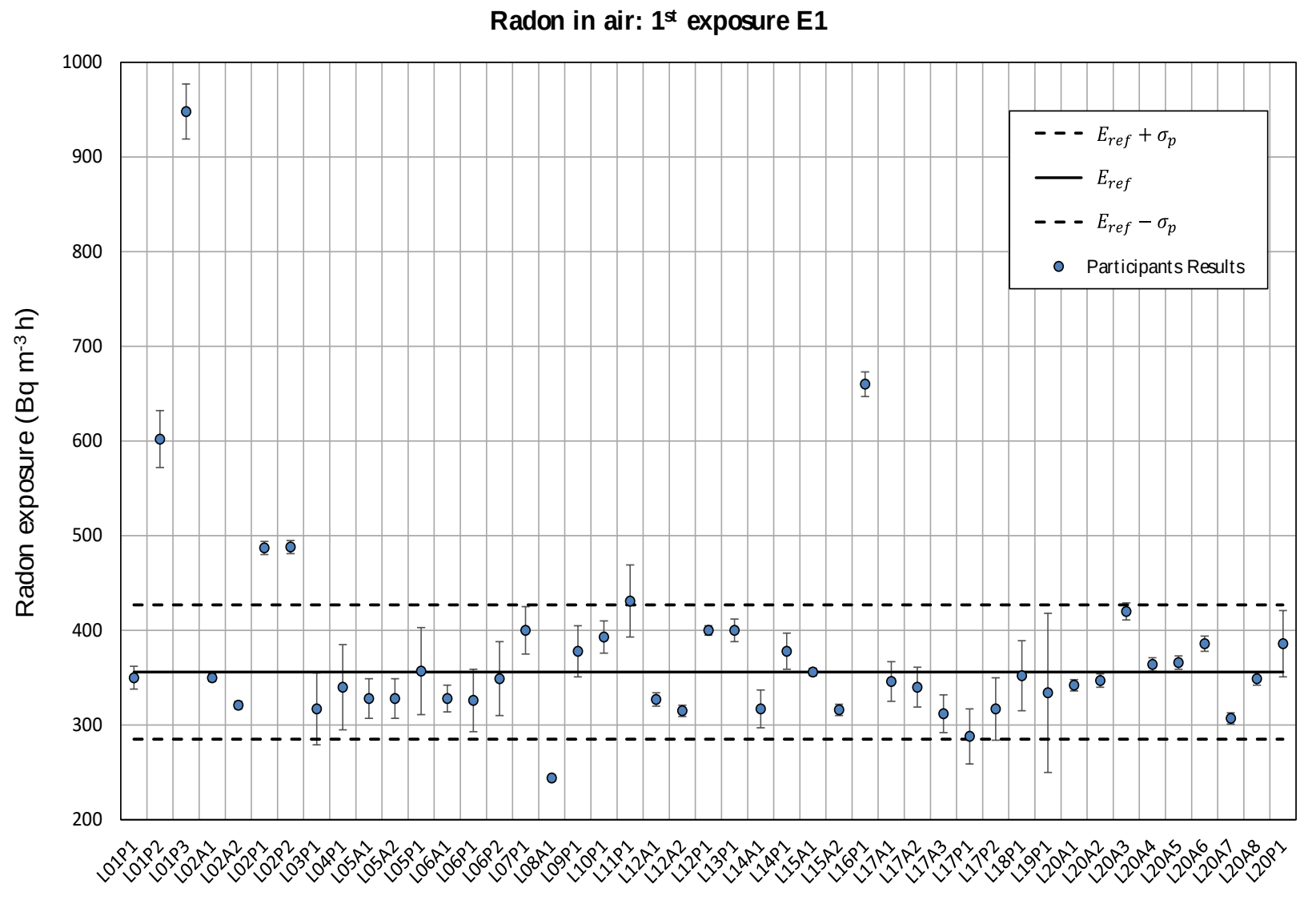
RESULTS

Exposure	E_{ref}	$u(E_{ref})$	σ_p	s^*	p
E1	356	8	71	43	45
E2	1014	13	101	68	41

Reference parameters of the first exposure E1 and second exposure E2 expressed in kBq m^{-3} h obtained from participant results according to ISO 13528:2015. *p* is the dimensionless number of results.

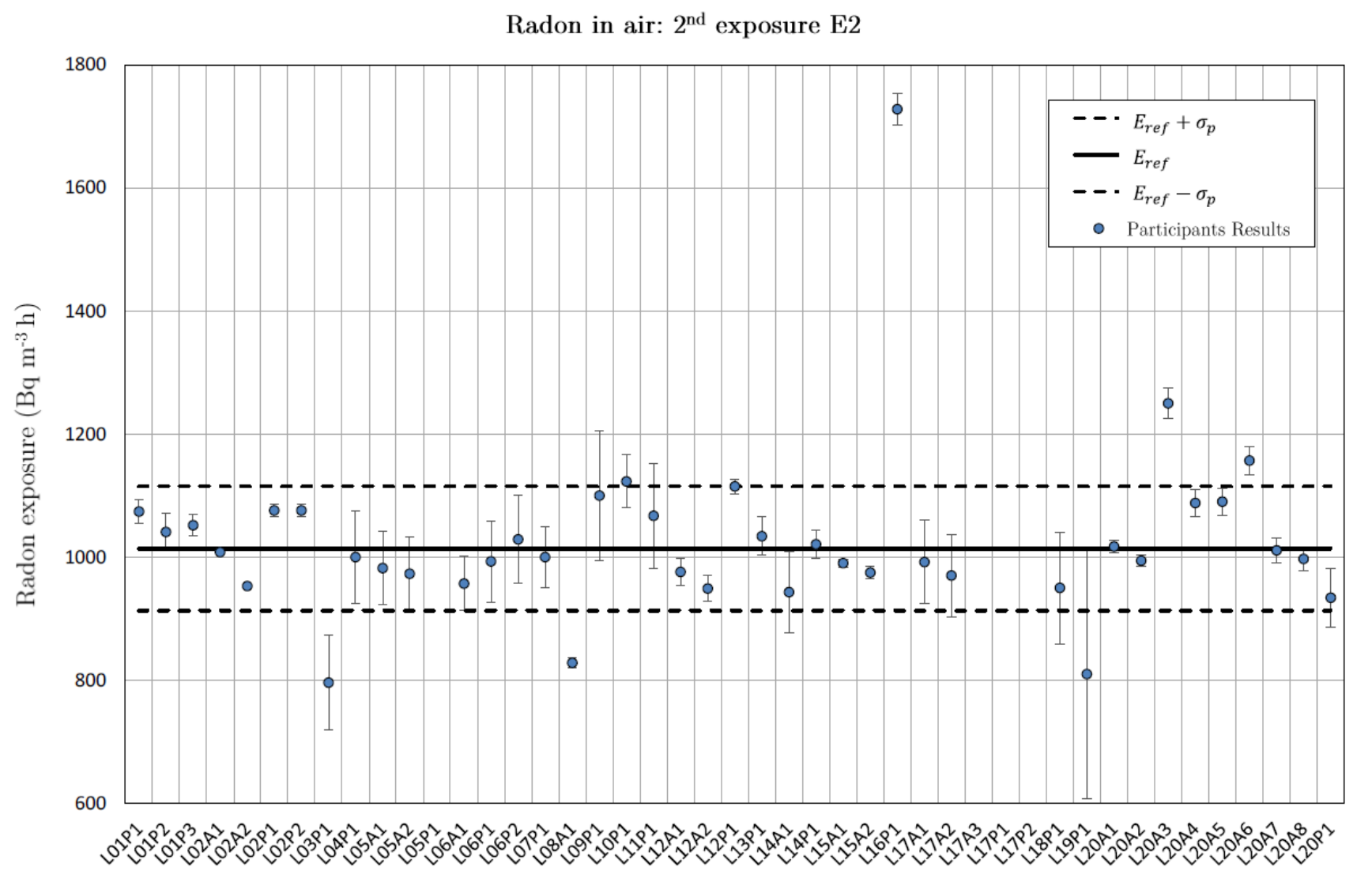
RESULTS

First Exposure

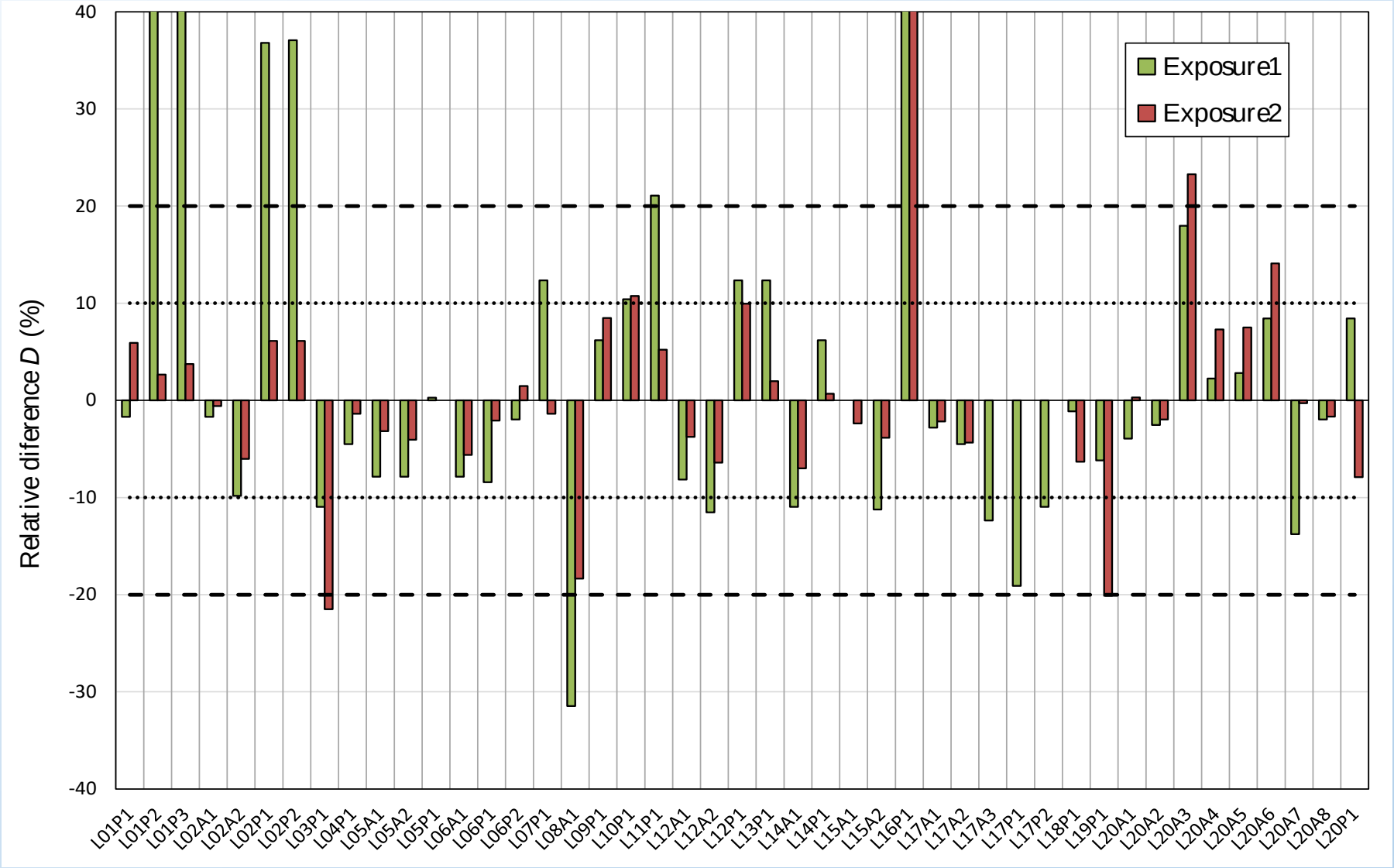


RESULTS

Second Exposure

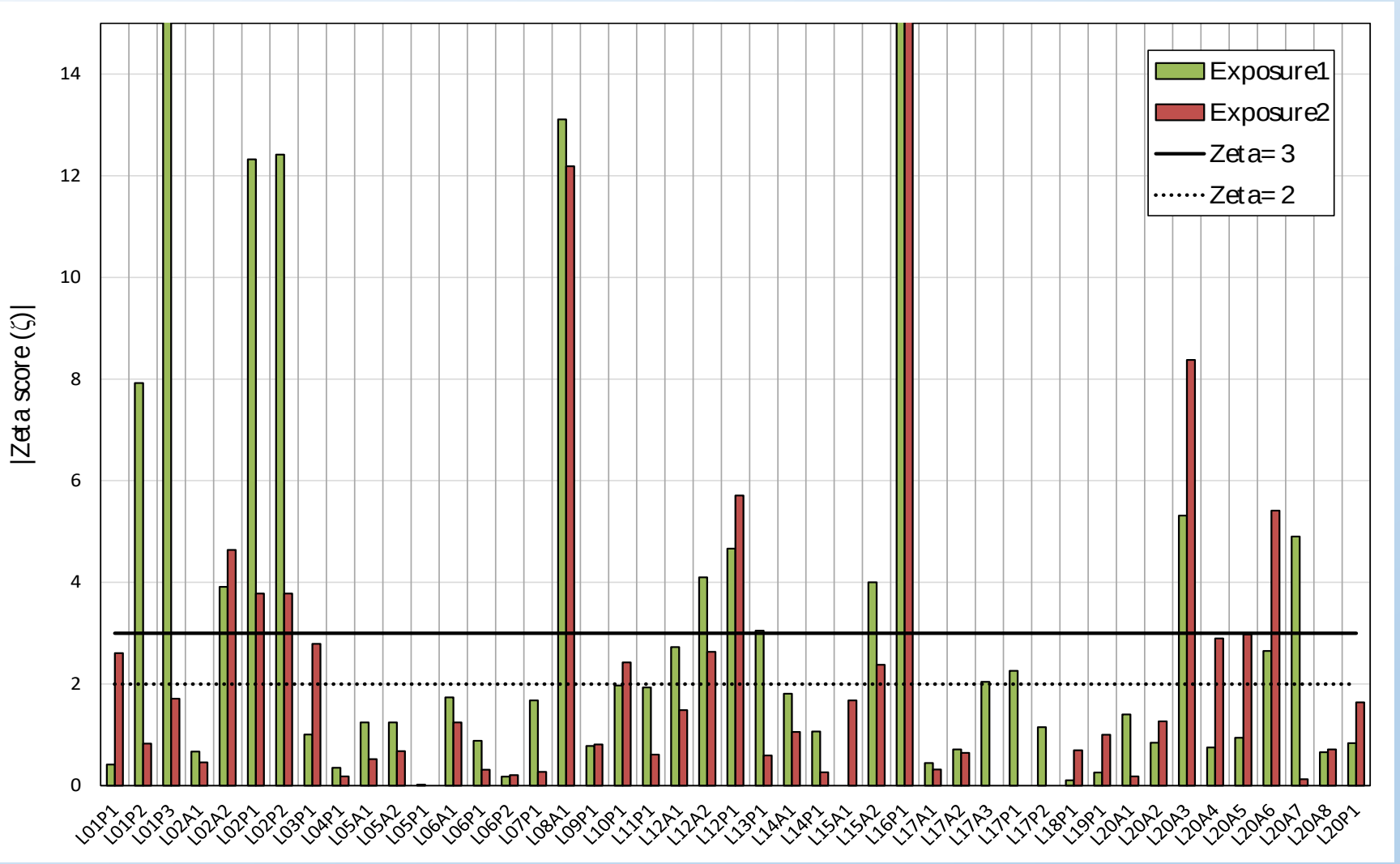


RESULTS



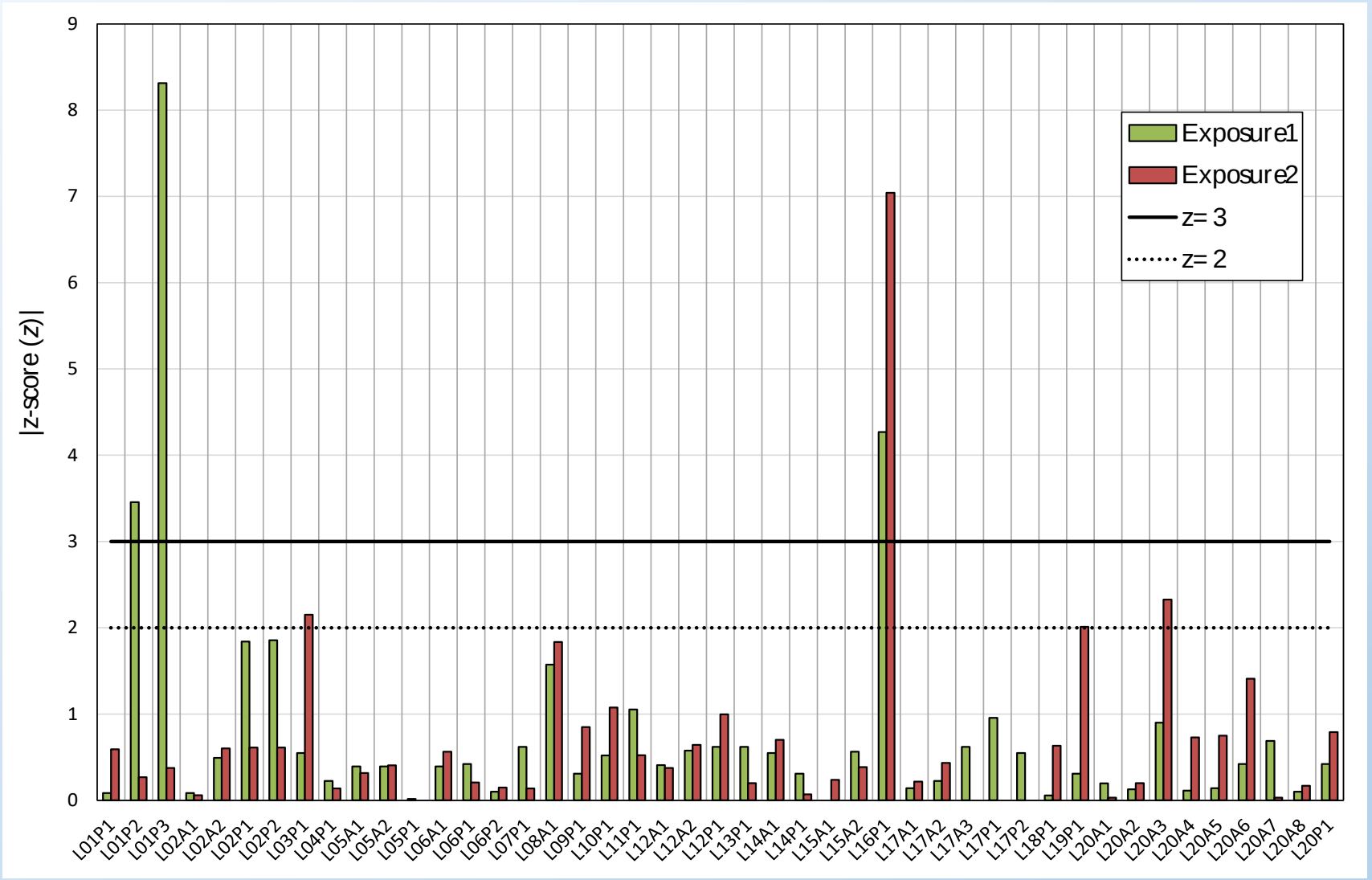
Relative difference of participant's results to the mean value for the first and second exposure. Intervals established for the first exposure (± 10%) and second exposure (± 20%) are indicated.

RESULTS



Absolute values of Zeta score for the first and second exposure.

RESULTS



Absolute values of z-score for the first and second exposure.

EXHALATION

A.3.3.4 – UC-JRC (Rn Exhalation and Rn in soil)

Laboratory of Natural Radiation

Green Ballesteros

EXHALATION

A.3.3.4 – UC-JRC (Rn Exhalation)

Code	J (Bq m^{-2} h^{-1})	$u(J)$ (Bq m^{-2} h^{-1})	Date (2018)	Methodology
L03E1	361	33	5 Nov 15:30 to 7 Nov 13:30	Gradient method with polycarbonate foils
L17E1	14719	1939	6 Nov 15:30 (approx. 1 hour.)	Accumulation method
L20E1	35100	8200	15 Nov 10:00 to 16 Nov 10:00	Absorption in activated charcoal collector

The participants did not perform the exhalation measurements during the same time and weather conditions due to the different methodologies involved, which could explain the widespread of results.

RADON IN SOIL

A.3.3.4 – UC-JRC (Rn in soil)

"Green Ballesteros"			
Code	C_{soil} (kBq m^{-3})	$u(C_{soil})$ (kBq m^{-3})	Methodology
L03S1	602	57	Absorption in polycarbonate foils
L10S1	546	143	Continuous monitoring
L13S1	789	74	Etched track detectors
L17S1	894	37	Continuous monitoring
L20S1	840	140	Grab sampling in ionization chamber plus measure with electrometer

Radon in soil results, between 550 and 900 kBq m^{-3}, are acceptable taking into account the arithmetic mean value and its standard deviation.

CONCLUSIONS

OVER 80% OF THE RESULTS FOR RADON IN AIR EXPOSURE ARE WITHIN THE INTERVAL DEFINED BY THE REFERENCE VALUE AND THE STANDARD DEVIATION

AROUND 90% OF LABS OBTAINED A SATISFACTORY z-SCORE FOR BOTH EXPOSURES

AROUND 60% OF RESULTS ARE SATISFACTORY REGARDING Z SCORE

IDENTIFICATION OF DEGASSING PROBLEMS IN SOME DETECTORS – FAST VARIATIONS IN RADON CONCENTRATION!

Thanks for your attention!