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CENTRO DE INVESTIGAÇÃO  
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LABORATÓRIO DE RADIOATIVIDADE NATURAL  
UNIVERSIDADE DE COIMBRA

# INDOOR RADON AND THORON LEVELS IN THE SOUTHWEST REGION OF ANGOLA

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# Objectives

## 1. Evaluate indoor radon ( $^{222}\text{Rn}$ ) and thoron ( $^{220}\text{Rn}$ ) concentrations:

- *Estimate the % of buildings above WHO and ICRP reference levels (100 and 300 Bq/m<sup>3</sup>)*
- *Assess the influence of building usage (dwellings vs. workplaces), building materials and underlying geological units;*

## 2. Estimate the total annual inhalation dose in dwellings and workplaces:

- *Estimate the % of workplaces surpassing the 1 mSv threshold set by the Council Directive 2013/59/EURATOM;*

# Materials & Methods

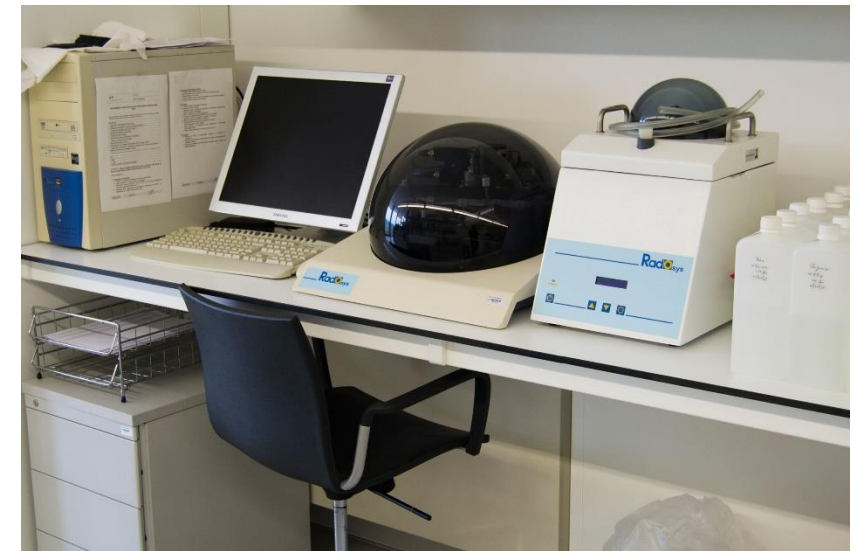
- **81 RADUET detectors** (Radosys Ltd.) placed between 0.8 to 2.0 m above ground level
- Average exposure: **3 months**
- Revelation of the detectors according to **ISO 11665-4:2020** (accredited method)
- Estimation of the **total annual inhalation dose**<sup>[4]</sup>:

$$\{(0.17 + 9 \times F_{Rn}) \times C_{Rn} + (0.11 + 40 \times F_{Tn}) \times C_{Tn}\} \times OF \times T \times 10^{-6}$$

$F_{Rn}$  and  $F_{Tn}$  - equilibrium factors for  $^{222}\text{Rn}$  and  $^{220}\text{Rn}$  progeny (0.4 and 0.02)<sup>[5]</sup>

$C_{Rn}$  and  $C_{Tn}$  - measured  $^{222}\text{Rn}$  and  $^{220}\text{Rn}$  activity concentrations (in  $\text{Bq}/\text{m}^3$ )

$OF$  is the occupancy factor (0.79 for dwellings and 0.2 for workplaces according to the Angolan Labor Law)



# Materials & Methods

Building usage

Building materials

Geological units



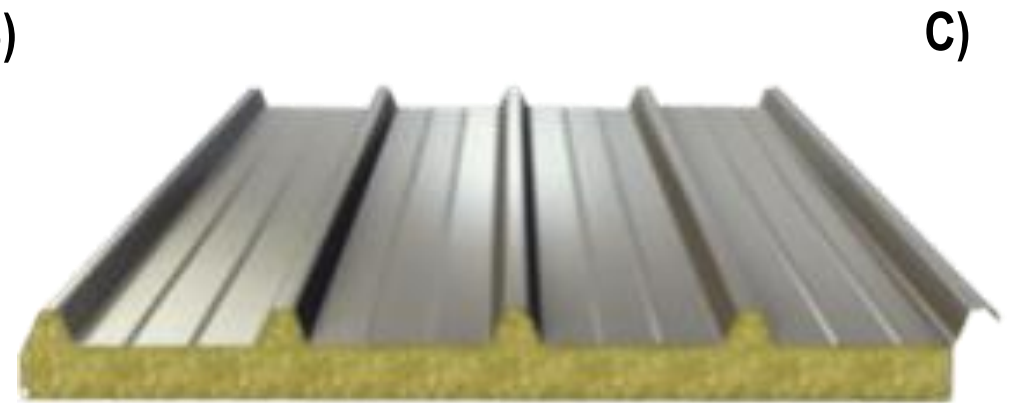
**Left:** Workplace constructed with metal plates; **Right:** Dwelling built with stones.

# Materials & Methods

Building usage

Building materials

Geological units



**A)** Clay (Adobe); **B)** Concrete block; **C)** Metal (metallic plates); **D)** filled clay brick; **E)** hollow clay brick; **F)** Stone;

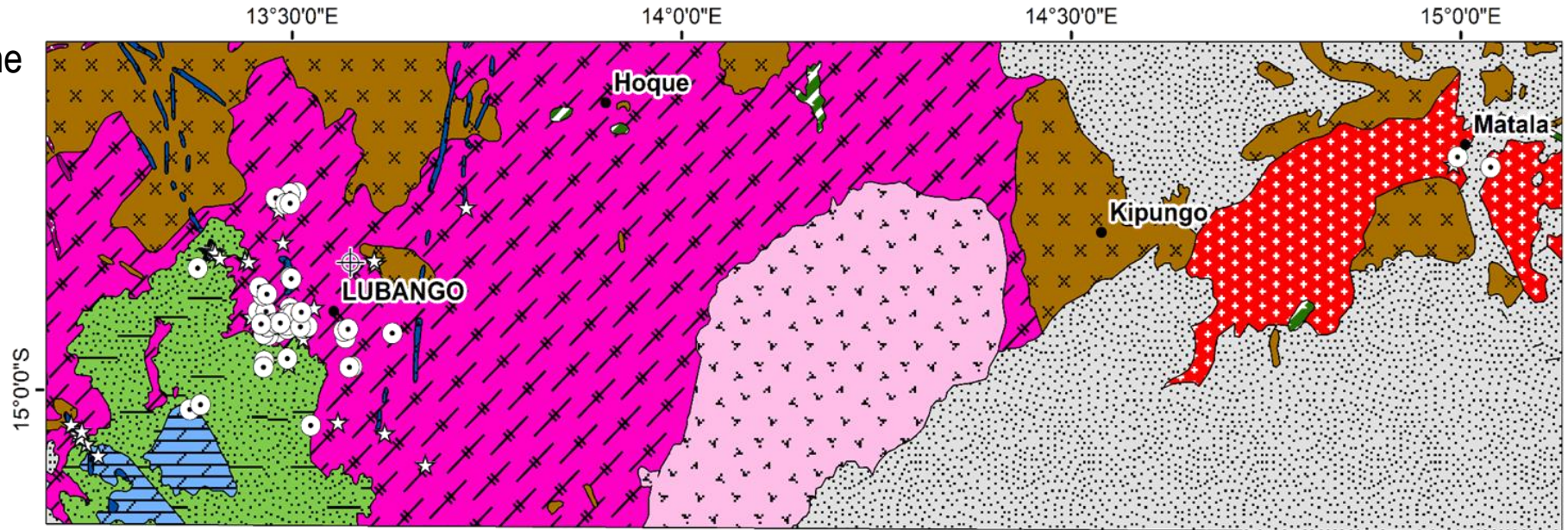
# Materials & Methods

Building usage

Building materials

Geological units

Adapted and reinterpreted from the Geological Map of Angola at the scale of 1: 1.000.000<sup>[1,2,3]</sup>



## Legend

- City
- ⊕ Borehole
- Indoor sampling site
- ☆ Bedrock sampling site

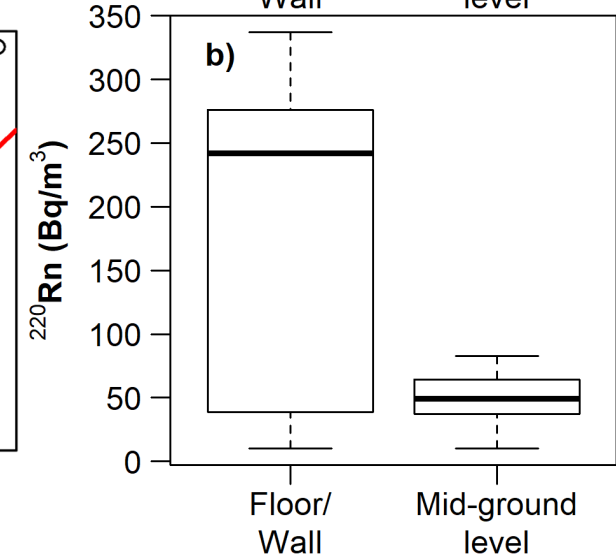
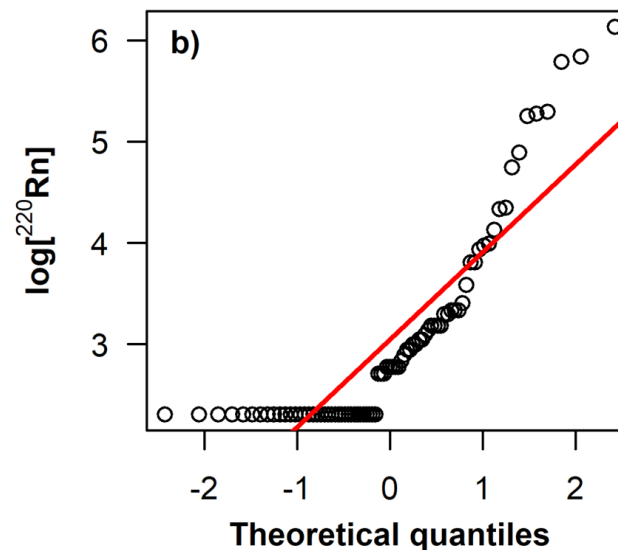
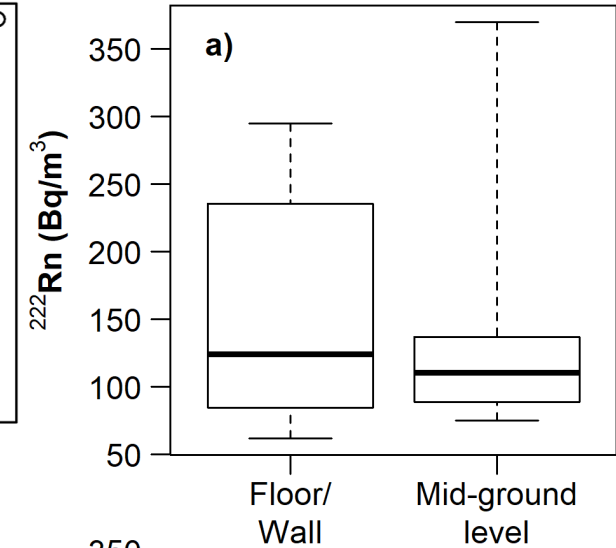
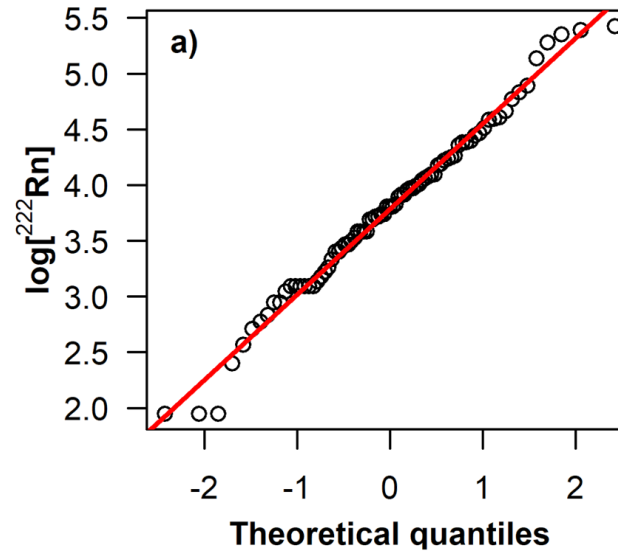
## Geology

- Cenozoic cover
- Mesozoic extrusive rocks
- Red granites and porphyries
- Anorthosite Complex
- Post-Eburnean mafic rocks
- Leba Formation
- Chela Group
- Eburnean granitoids and migmatites
- Eburnean metasedimentary rocks
- Pre-Eburnean basement

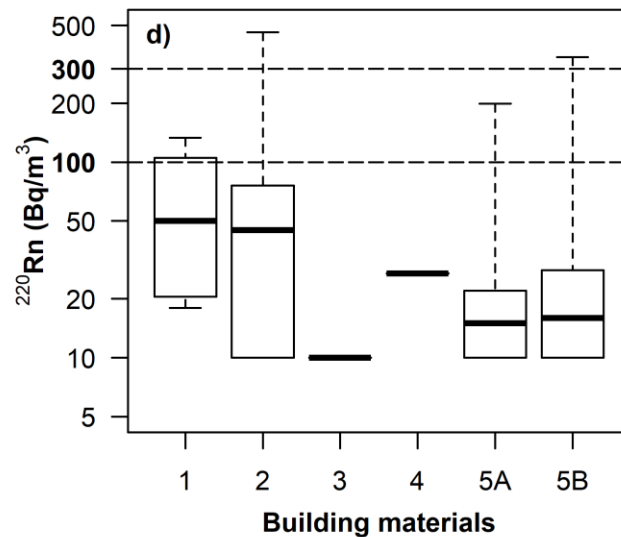
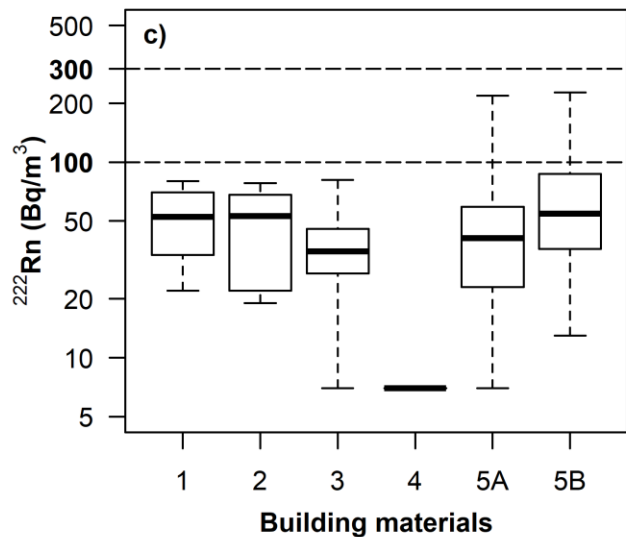
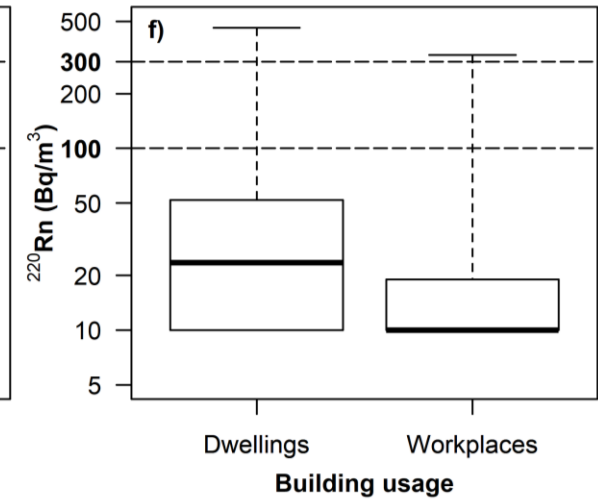
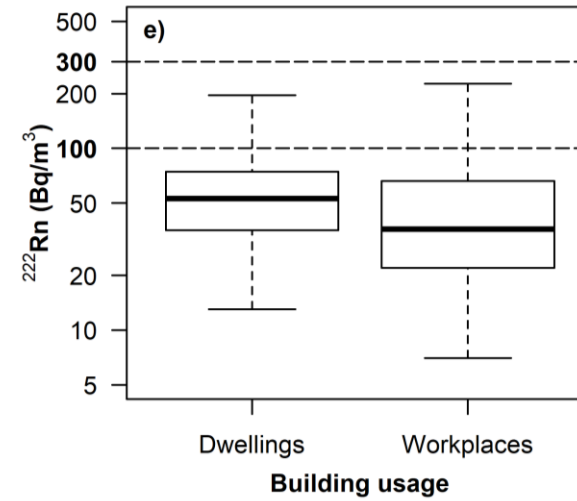
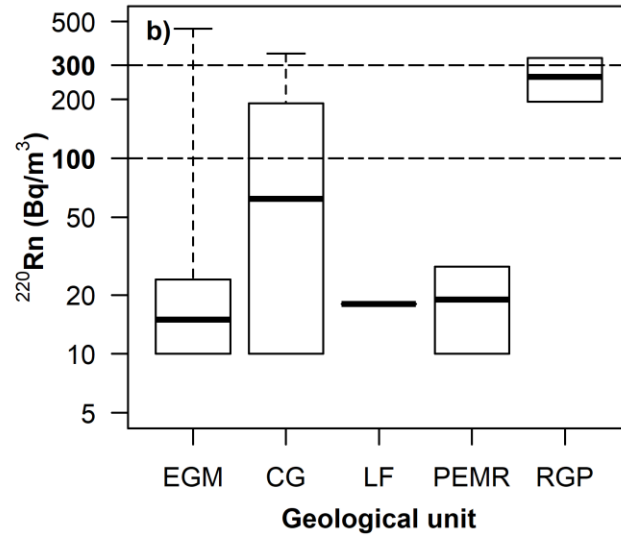
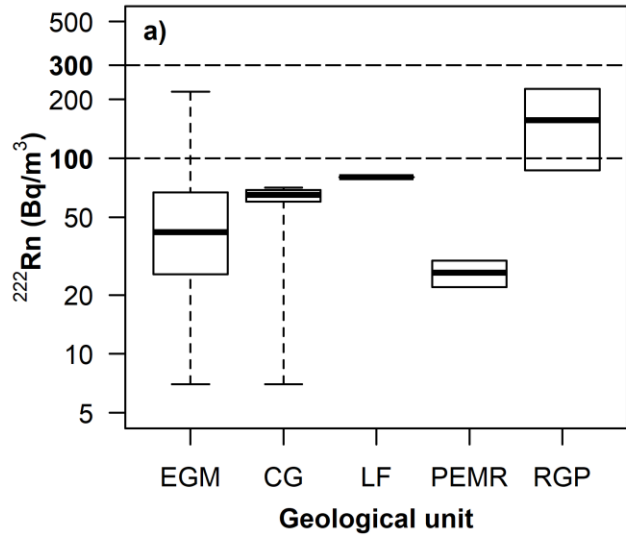


# Results & Discussion: Indoor radon and thoron concentrations

	$^{222}\text{Rn}$ (Bq/m <sup>3</sup> )	$^{220}\text{Rn}$ (Bq/m <sup>3</sup> )	Total Rn <sup>a</sup> (Bq/m <sup>3</sup> )	$^{222}\text{Rn}/$ $^{220}\text{Rn}$
Number of samples	81	81	81	81
Mean	58	42	100	3/1
Standard deviation	47	78	94	3/1
Minimum	7	10	17	1/21 (95%)
First quartile	26	10	44	1/1
Median	45	16	67	3/1
Third quartile	70	28	109*	5/1
Maximum	227	461*	483*	12/1 (92%)
Number of samples below the LLD	3 (4%)	39 (48%)	-	-
N ≥ 300 Bq/m <sup>3</sup>	0 (0%)	3 (4%)	4 (5%)	-
Shapiro Wilk test (p-value)	<0.001	<0.001	<0.001	-
Spearman Rank Correlation	R = 0.10, p-value = 0.377			
<sup>a</sup> Sum of indoor $^{222}\text{Rn}$ and indoor $^{220}\text{Rn}$ activity concentration.				



# Results & Discussion: Indoor radon and thoron concentrations



*Geological units:* EGM – Eburnean granitoids and migmatites; CG – Chela Group; LF – Leba Formation; PEMR – Post-Eburnean Mafic Rocks; RGP – A-type red granites and porphyritic rhyolites;

*Building materials:* 1 – Clay; 2 – Concrete; 3 – Metal; 4 – Stone; 5 – Brick (5A – filled brick; 5B – hollow brick).



# Results & Discussion: Total annual inhalation dose (in mSv/y)

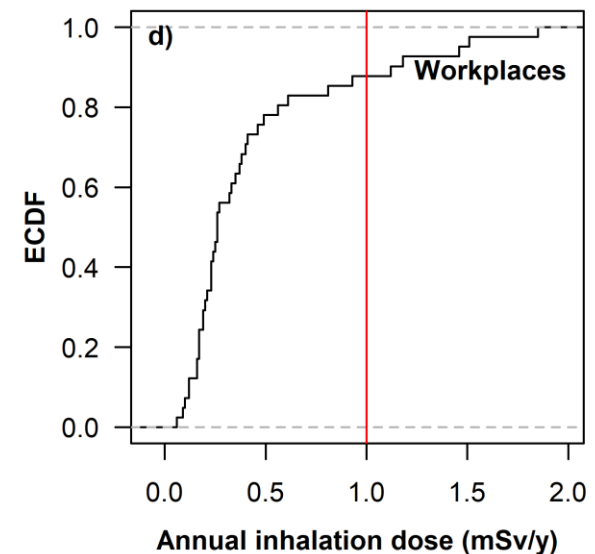
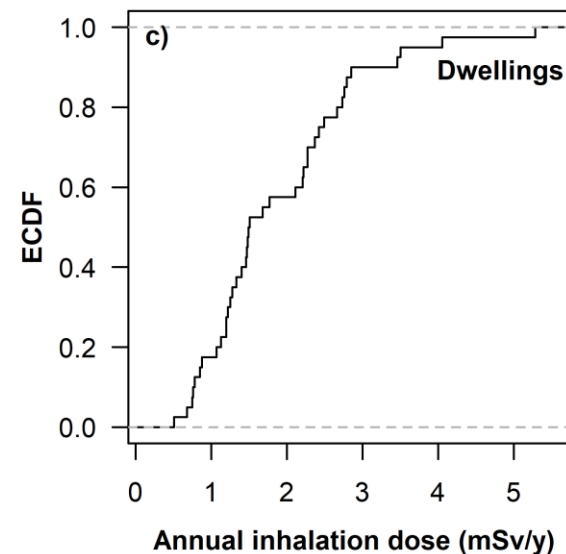
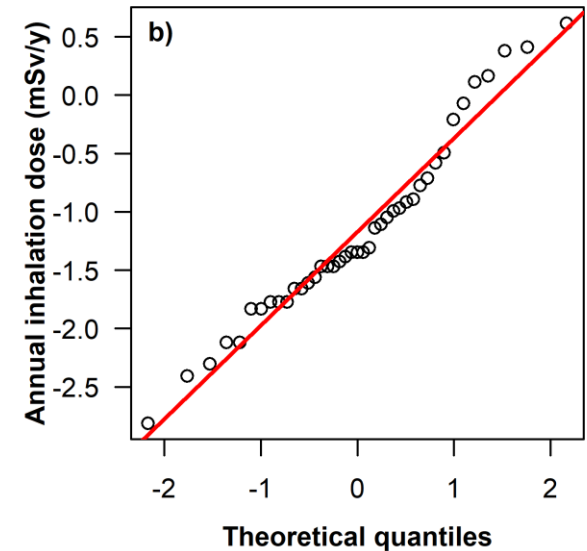
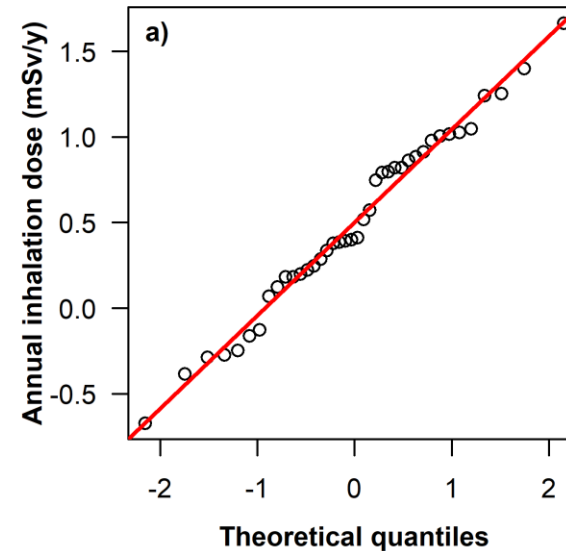
		OF	N	AM	SD	Min	Q25	Med	Q75	Max	MAD	CV
Building usage	Dwellings	0.79	40	1.89	1.02	0.51	1.20	1.50	2.44	5.28	1.06	54
	Workplaces	0.20	41	0.44	0.42	0.06	0.19	0.26	0.46	1.85	0.15	95
Building materials	Clay	0.79	4	1.76	0.66	1.07	1.27	1.78	2.27	2.42	0.81	38
	Concrete	0.79	9	1.86	0.97	0.76	0.85	2.11	2.27	3.50	1.01	52
	Metal	0.79	8	1.06	0.56	0.25	0.84	0.99	1.26	2.19	0.41	53
	Stone	0.79	1	0.36	nd	nd	nd	nd	nd	nd	nd	nd
	Filled brick	0.79	29	1.70	1.42	0.39	0.78	1.22	2.37	5.88	0.70	84
	Hollow brick	0.79	30	2.11	1.58	0.46	1.07	1.50	2.69	7.20	1.02	75
Geological unit	EGM	0.79	71	1.67	1.21	0.36	0.89	1.28	2.23	5.88	0.77	72
	CG	0.79	5	2.21	1.39	0.25	1.77	2.21	2.79	4.05	0.86	63
	LF	0.79	1	2.22	nd	nd	nd	nd	nd	nd	nd	nd
	PEMR	0.79	2	0.80	0.06	0.76	0.78	0.81	0.83	0.85	0.07	8
	RGP	0.79	2	5.78	2.02	4.35	5.06	5.78	6.49	7.20	2.11	35

*Variables:* OF – Occupancy factor; AM – Arithmetic mean; SD – Standard deviation; Min – Minimum; Q25 – First quartile; Med – Median; Q75 – Third Quartile; Max – Maximum; MAD – Median absolute deviation; CV – Coefficient of variation;

*Geological units:* EGM – Eburnean granitoids and migmatites; CG – Chela Group; LF – Leba Formation; PEMR – Post-Eburnean Mafic Rocks; RGP – A-type red granites and porphyritic rhyolites; nd – not determined

# Results & Discussion: Total annual inhalation dose (in mSv/y)

- **Log-normal distribution** (dwellings and workplaces)
- **Dwellings:** 0.51 to 5.28 mSv/y, with a median of 1.50 mSv/y;
- **Workplaces:** 0.06 to 1.85 mSv/y, with a median of 0.26 mSv/y;
- **1 mSv threshold** established in the Council Directive 2013/59/EURATOM is exceeded in **12% of workplaces**;



# Conclusions & Implications

- Indoor radon levels are **generally below 300 Bq/m<sup>3</sup>**
- The **contribution of <sup>220</sup>Rn to the total indoor radon activity concentration averages 35%**, but may reach 95%
- Highest indoor <sup>222</sup>Rn, <sup>220</sup>Rn and AID values: **A-type red granites and porphyritic rhyolites**
- Higher indoor <sup>220</sup>Rn and AID values: **Clay, concrete and hollow brick-based constructions**
- Higher indoor <sup>222</sup>Rn, <sup>220</sup>Rn and AID values: **Dwellings**
- **Indoor <sup>222</sup>Rn and indoor <sup>220</sup>Rn are not correlated** indicating **both must be estimated independently** for a proper estimation of the contribution of <sup>220</sup>Rn to the AID

*\*This work is submitted to the Environmental Geochemistry and Health Journal*

# References

- [1] LNICT (1980). Geologia de Angola, Carta na Escala 1/1000000, coordenada por Heitor de Carvalho, Laboratório Nacional de Investigação Científica Tropical, Folha nº 3.
- [2] Pereira, E., Rodrigues, J.F., Tassinari, C.C.G., Van-Dúnem, M.V. (2013a). Geologia da Região de Lubango, SW de Angola. Evolução no contexto do cratão do Congo. Instituto Geológico de Angola, 160 p.
- [3] Pereira, E., Rodrigues, J., Van-Dúnem, M.V. (2013b). Carta Geológica de Angola, à escala 1: 250 000: Folha Sul D-33/T (Chibia). Publicação do Instituto Geológico de Angola.
- [4] UNSCEAR, United Nation Scientific Committee on the Effect of Atomic Radiation (2000). Annex B: Exposures from Natural Radiation Sources. United Nations, p. 104.
- [5] UNSCEAR, United Nations Scientific Committee on the Effects of Atomic Radiation (2010). Source and effects of ionizing radiation. UNSCEAR 2008, report to the general assembly with scientific annexes, I, 463 p.
- \*Baptista, E., Pereira, A.J.S.C., Domingos, F.P., Sêco, S.L.R. Radon and thoron concentrations in the Southwest region of Angola: Dose assessment and implications for risk mapping. *Submitted to the Environmental Geochemistry and Health.*

12 90

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# THANK YOU FOR YOUR ATTENTION!

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