



RADON CONCENTRATIONS ON THE NUCLEAR AND RADIOACTIVE INSTALATIONS OF NUCLEAR REACTOR CENTER – CRPQ/IPEN



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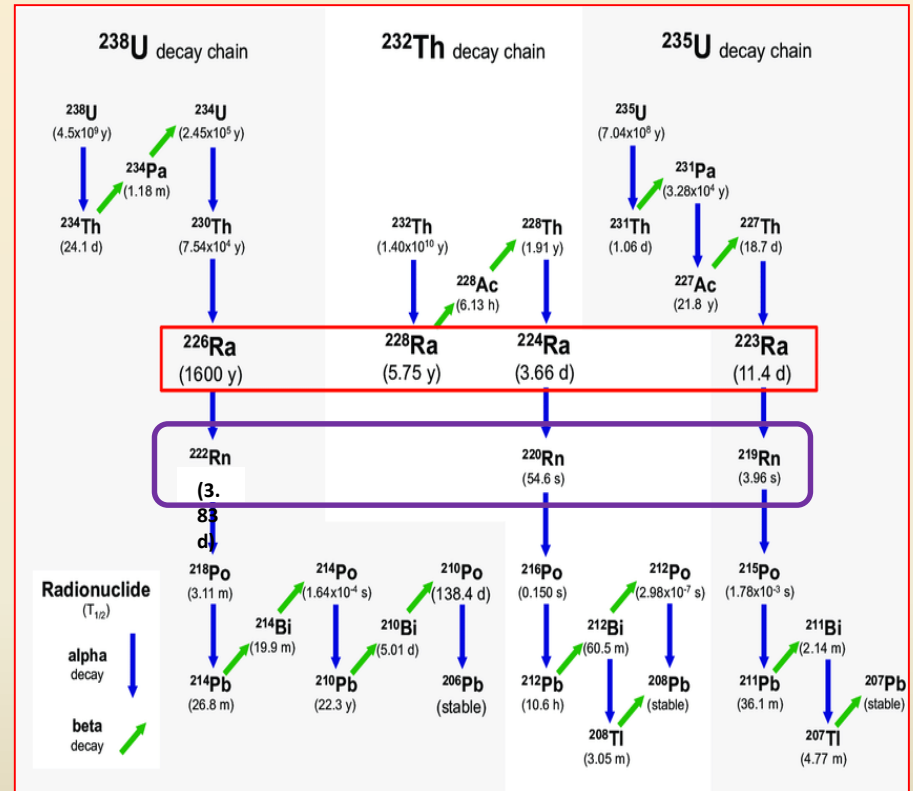
Marcia Pires de Campos

Guilherme de Lima Reis

INTRODUCTION

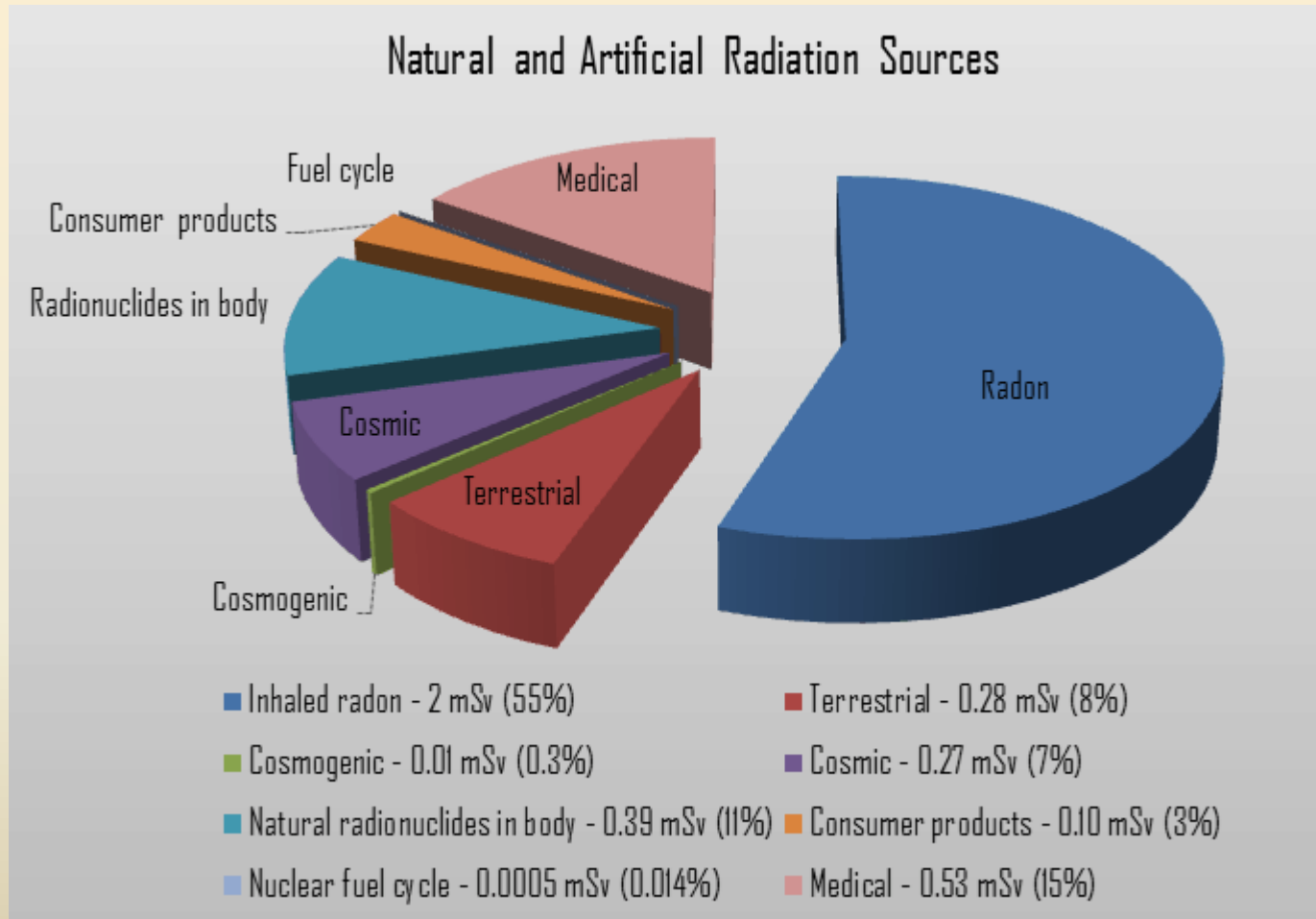
Radon

- Naturally occurring radioactive gas;
- Alpha emitter;
- Its decay products are themselves radioactive;
- Have half-lives shorter than that of radon;
- The decay products of radon are normally referred to as radon progeny;
- ^{218}Po , ^{214}Pb , ^{214}Bi and ^{214}Po ;
- These decay products attach themselves to aerosols.



INTRODUCTION

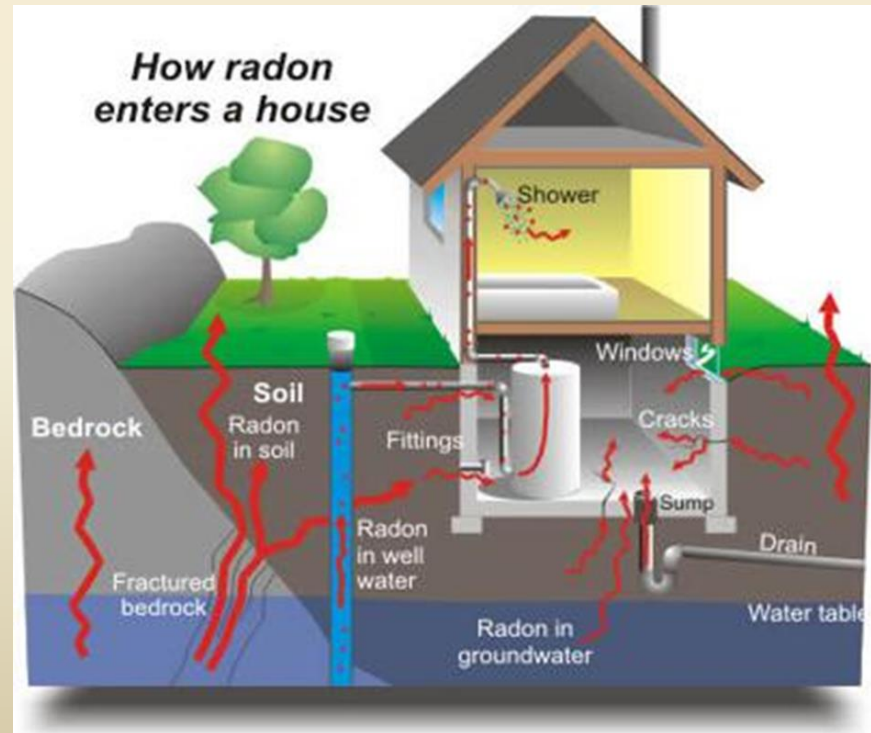
Natural and Artificial Radiation Sources



INTRODUCTION

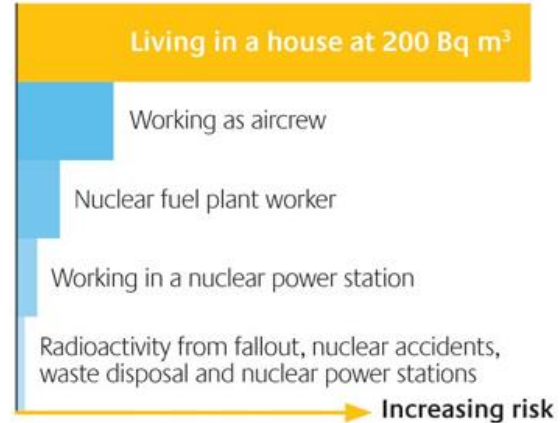
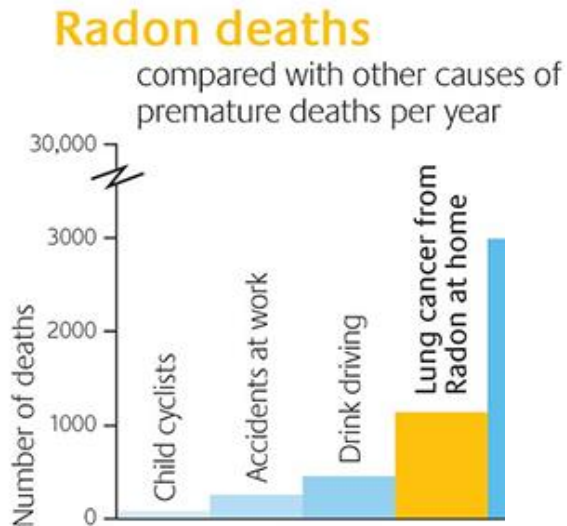
- Radon levels outdoors are typically very low.
- Can be higher in buildings, homes, workplaces.
- Especially underground such as in tourist caves and mines.

Building materials containing ^{238}U or ^{226}Ra may release radon into the indoor environment.



INTRODUCTION

The excess lifetime risk of death from radon-induced lung cancer (by the age of 75 years) is estimated to be 0.6×10^{-5} per Bq/m^3 for lifelong non-smokers.



INTRODUCTION

World Health Organization

- Recommended action level - 100 Bq m^{-3}
- Not higher than - 300 Bq m^{-3}

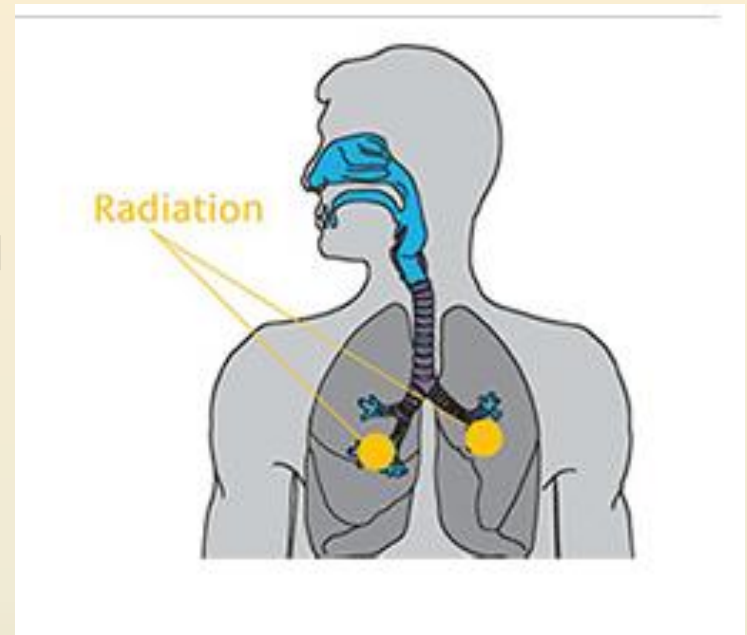
International Commission on Radiological Protection (ICRP)

- Action level for non-related nuclear and radioactive workers - 500 to 1500 Bq m^{-3} ,

The Health and Safety Executive - United Kingdom

- Action level of 400 Bq m^{-3} for workplaces

Other countries: Estonia (200 Bq m^{-3}), United States (150 Bq m^{-3}).



INTRODUCTION

| Annual Dose Limits CNEN | | | |
|----------------------------|-------------------|---|-------------------|
| Quantity | Organ | Occupationally exposed person | Public individual |
| Effective Dose | Whole body | 20 mSv [a] | 1 mSv |
| Equivalent Dose | lens of the eye | 20 mSv [a] (Amended by Resolution CNEN 114/2011) | 15 mSv |
| | Skin | 500 mSv | 50 mSv |
| | Hands and feet | 500 mSv | --- |

[a] Arithmetic average over 5 consecutive years, provided it does not exceed 50 mSv in any year.

Motivation

Radon monitoring

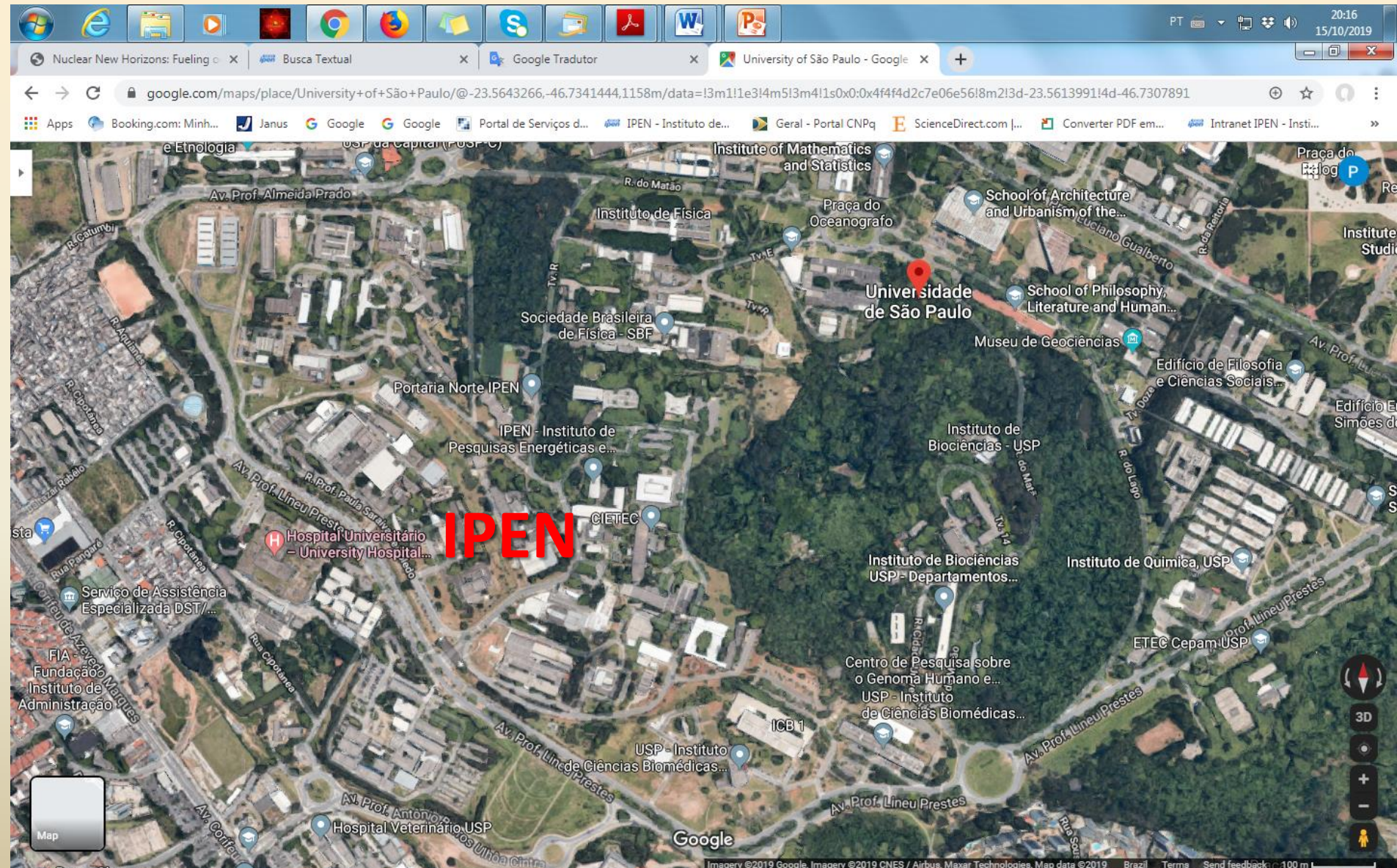
- ✓ Buildings
- ✓ Workplaces
- ✓ Caves
- ✓ Underground places

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- There are few data on the radon levels in nuclear and radioactive workplaces other than uranium mining
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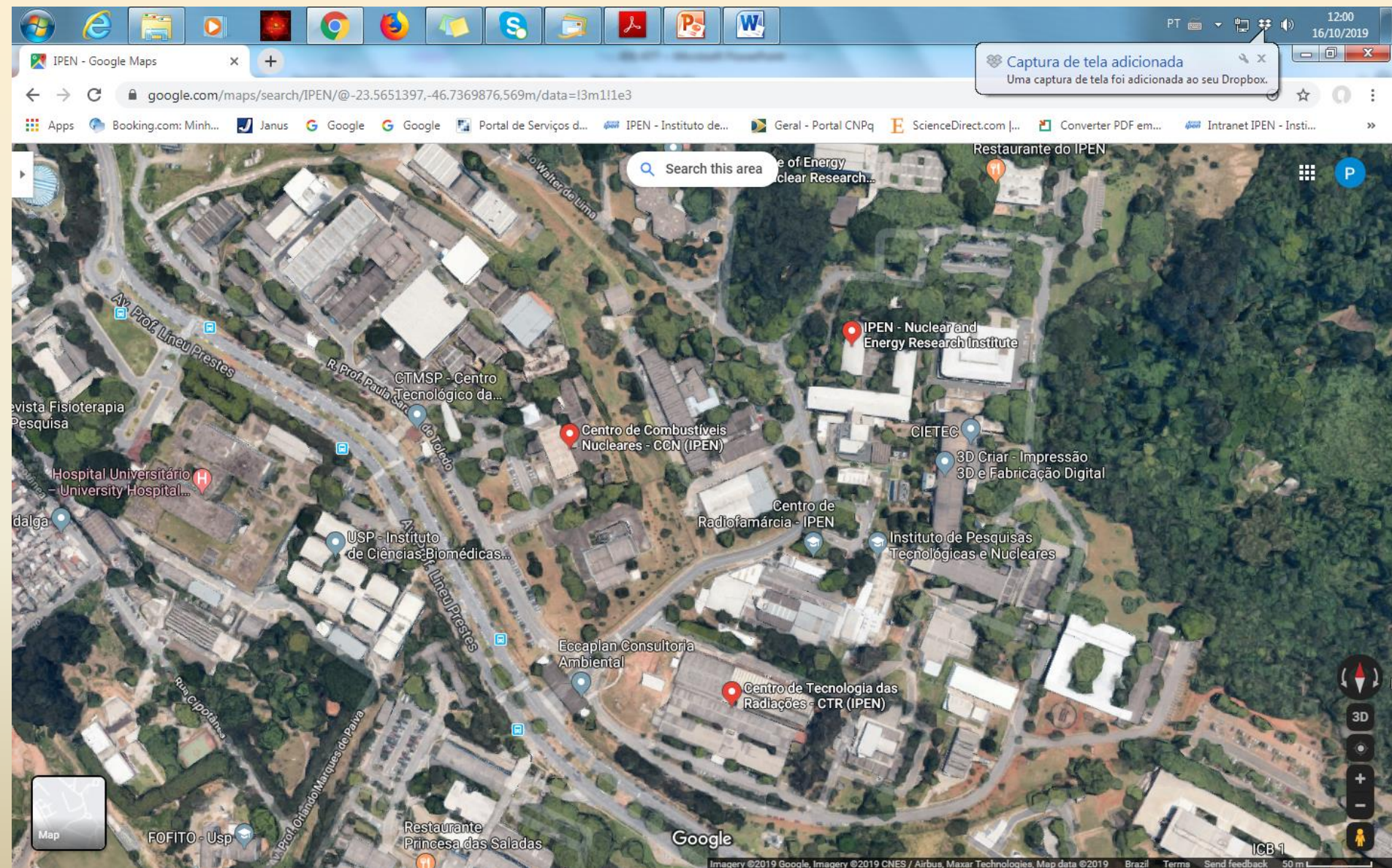
Objective

Describe the radon activity concentrations in the radioactive laboratories and nuclear installations of the Centro do Reator de Pesquisa – CERPq, a unity of the Instituto de Pesquisas Energéticas e Nucleares – IPEN, located in the Cidade Universitária, São Paulo.

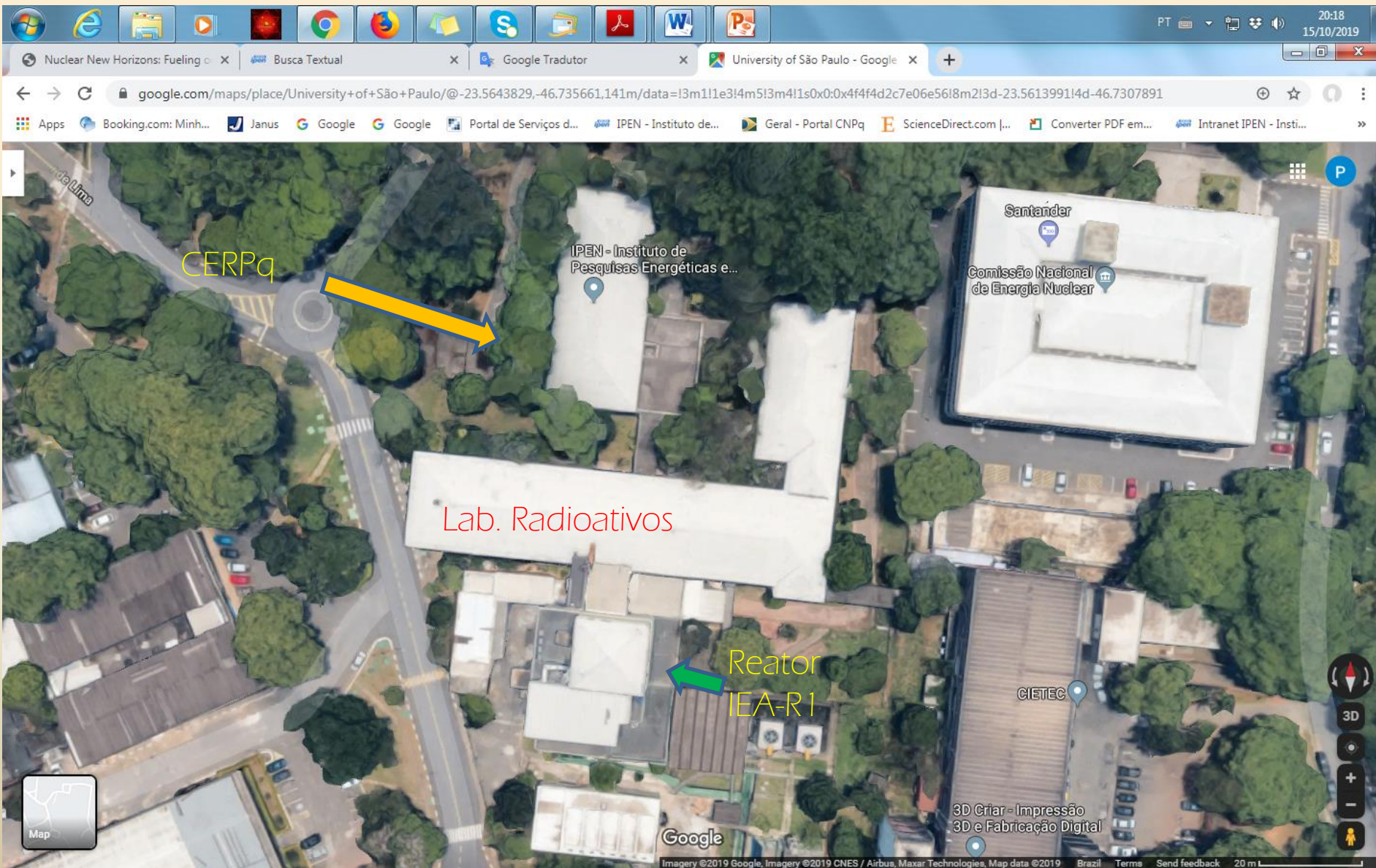
IPEN



IPEN



Research Reactor Center



Reactor Construction - 1956

Start-up - 1958

Concrete and Steel Walls



Research Reactor Center

Reactor Building



Radiochemical and Radiometric Laboratories

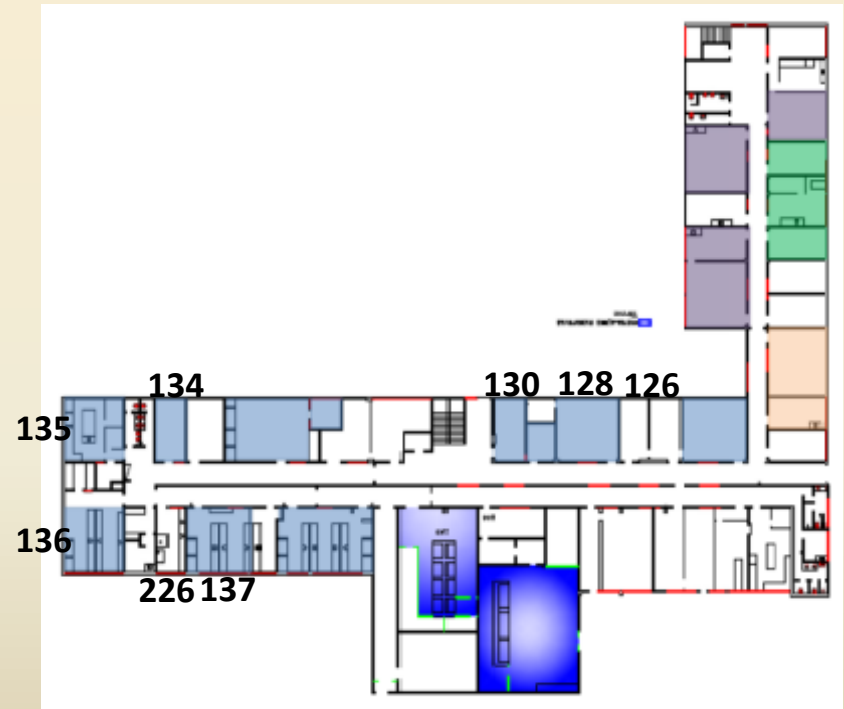


Photo: Katia Itioka

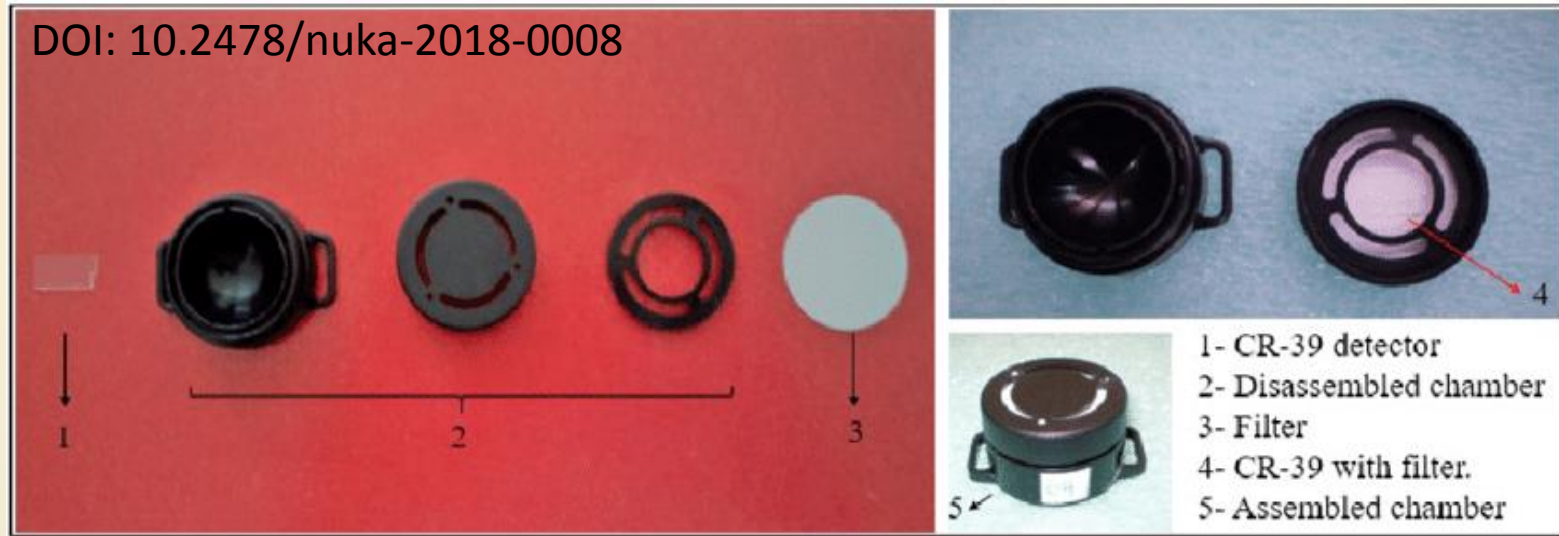
METHODOLOGY

Radon Measurement: RAD7

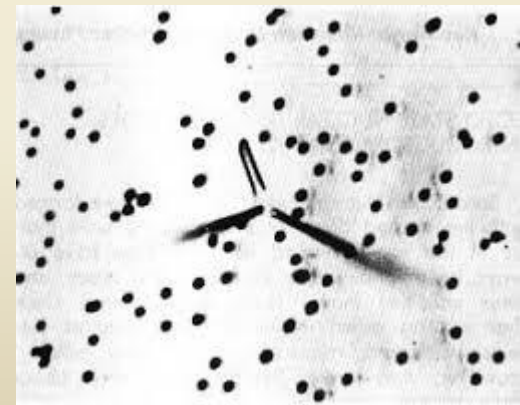


- ✓ Solid state ion implanted silicon alpha detector.
- ✓ Converts α radiation to an electric signal.
- ✓ The ^{222}Rn activity concentrations are determined by the decay of ^{218}Po and ^{214}Po .
- ✓ Internal volume: 0.7 L.
- ✓ Calibration accuracy: guaranteed by the manufacturer 5%.

Radon Measurement: SSNTD



- CR-39 presents better optical quality.
- After exposure: chemical attack with KOH, 30% (w/v), 5.5 h at 80 °C.
- ZEISS microscope with increase of 10x.
- Video camera Zeiss ICC-1 and a microcomputer.



SSNTD calculations

$$C_{\text{Rn}} = D / (k \cdot t)$$

C_{Rn} = ^{222}Rn concentration (Bq/m³);

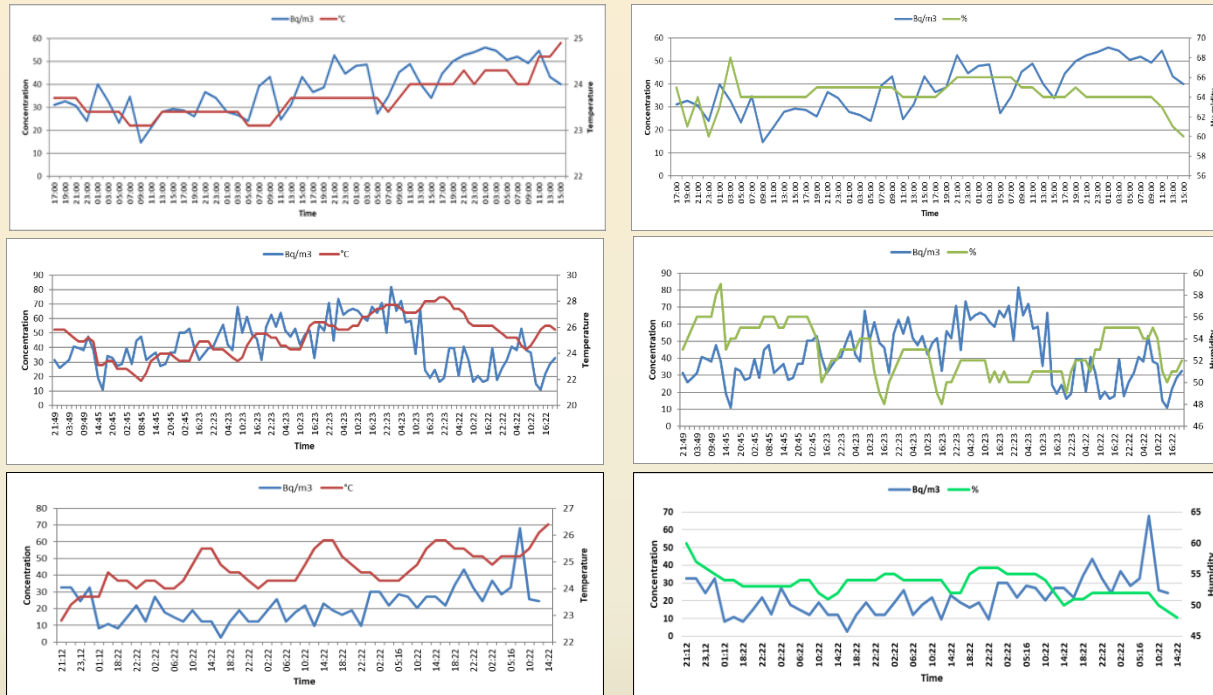
k = calibration factor (traces/cm² per Bq/m³d);

D = Net trace density (- background) (traces/cm²);

t = exposure time (d).

RESULTS AND DISCUSSION

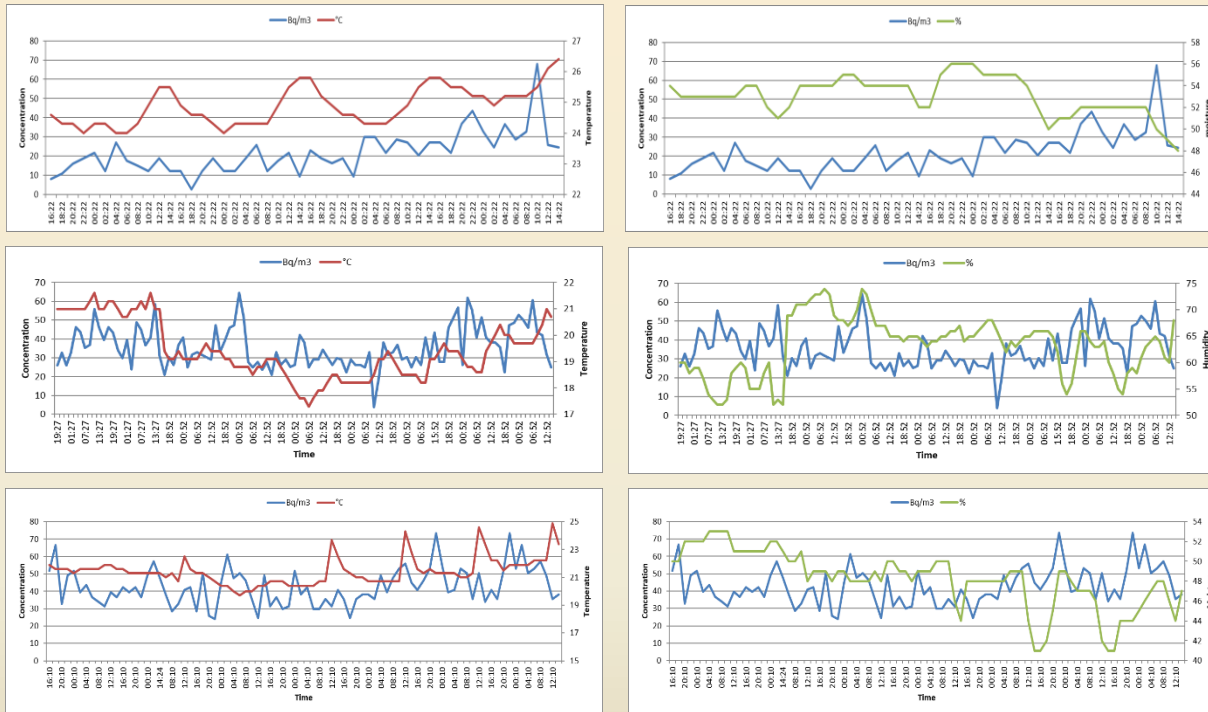
Radon concentration (Bq m^{-3}), temperature ($^{\circ}\text{C}$) and air humidity (%) in the radiochemical laboratories.



- Temperature and humidity do not vary in a great extension.
- Variation of temperature: $< 6\%$
- Variation of humidity: $< 5\%$
- Mean values ^{222}Rn concentration 23 to 42 Bq m^{-3} .
- Highest values: room 135, 82 Bq m^{-3} .

RESULTS AND DISCUSSION

Radon concentration (Bq m^{-3}), temperature ($^{\circ}\text{C}$) and air humidity (%) in the radiometric laboratories.



Temperature: varied from 19.4 to 21.4 °C

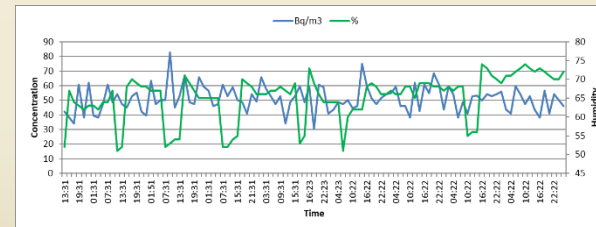
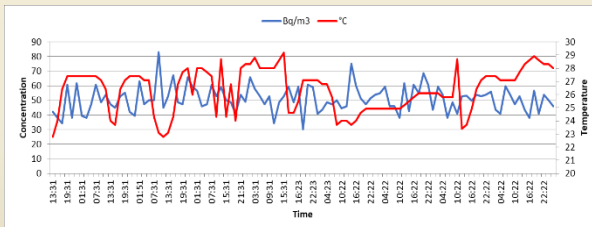
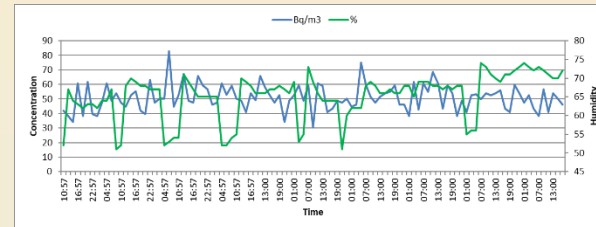
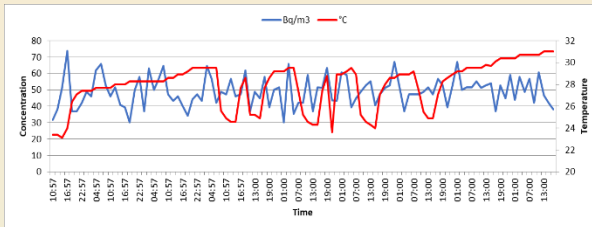
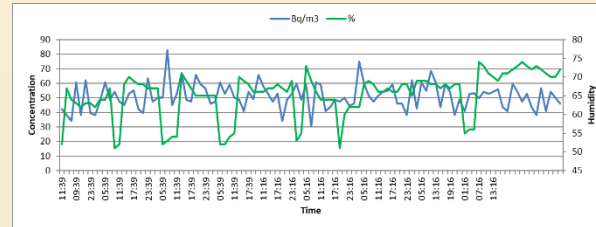
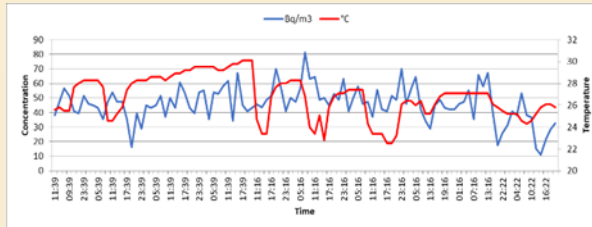
Humidity: variation 48.2 to 63.2%

Mean ²²²Rn concentration: 36 to 43 Bq m⁻³

Higher: room 126, 89 Bq m⁻³

RESULTS AND DISCUSSION

Radon concentration (Bq m^{-3}), temperature ($^{\circ}\text{C}$) and ai humidity (%) in the hall of the reactor pool (two measurements (1) and (2)) and the laboratory of the reactor first floor.



Hall of the reactor pool and the physics laboratory of the first floor

Temperature: $< 7.8^{\circ}\text{C}$

Humidity : $< 11.1\%$.

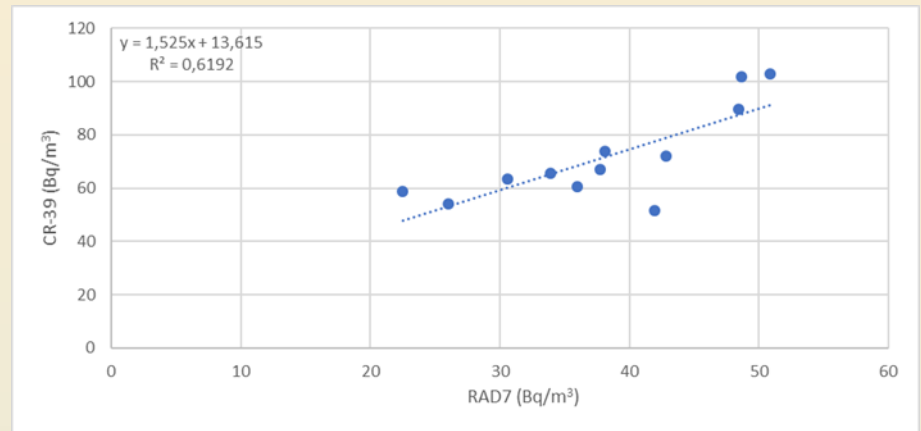
Mean ^{222}Rn concentrations: 48 to 51 Bq m^{-3}

Highest value: in the first floor, 83 Bq m^{-3} .

RESULTS AND DISCUSSION

Radon concentration (Bq m^{-3}) obtained by RAD7 and CR-39 and dose assessment (mSv a^{-1})

| | C (Bq/m^3) | | E (mSv a^{-1}) |
|--------------------|-----------------------|-------|---------------------------|
| | RAD7 | CR-39 | |
| Radiochemical labs | | | |
| 134 | 38 | 74 | 0.44 |
| 135 | 42 | 52 | 0.31 |
| 136 | 23 | 59 | 0.35 |
| 137 | 26 | 54 | 0.32 |
| 139 | 34 | 66 | 0.39 |
| 226 | 31 | 63 | 0.38 |
| Radiometric labs | | | |
| 126 | 38 | 67 | 0.40 |
| 128 | 36 | 60 | 0.36 |
| 130 | 43 | 72 | 0.43 |
| Reactor | | | |
| R1 | 48 | 90 | 0.54 |
| R1 | 49 | 102 | 0.61 |
| FF | 51 | 103 | 0.72 |



Linear regression obtained for radon concentration (Bq m^{-3}) measured by RAD7 and CR-39

RESULTS AND DISCUSSION

| | | Mean | Range | |
|------------------------|------------------------|-------|--------------|------|
| Palakkad, India | Dwelling | 28.1 | 15 - 79 | 2017 |
| Al-kharj, Saudi Arabia | Dwelling | 114 | 67 - 488 | 2014 |
| | Workplace | 76 | 46 - 267 | |
| South- Day, Gana | Indoor | 24.9 | 27 - 42.8 | 2018 |
| Eastern Sicily, Italy | Indoor | 53 | 24 - 126 | 2012 |
| Brisbane, Australia | Workplace | 10.5 | 0.7 - 86.6 | 2015 |
| Catalonia, Spain | Workplace, Underground | | < 1 – 12.900 | 2008 |
| Mexico City, Mexico | Dwelling | 28 | | 2009 |
| | Workplace | 123 | | |
| Guadalajara | Dwelling | 80 | | |
| | Workplace | 160 | | |
| Monterrey | Dwelling | 42 | | |
| | Workplace | 69 | | |
| Stan Ter, Kosovo | Workplace, underground | 281.4 | 60 – 748 | |
| Italy | Workplace, underground | 723 | 7 – 43.919 | 2009 |
| São Paulo, Brazil | Caves (PETAR) | | 515 – 6.607 | 2005 |

This study

- ✓ Highest Value Radiochemical Laboratories: 82 Bq m⁻³.
- ✓ Highest Value Radiometric Laboratories: 89 Bq m⁻³.
- ✓ Highest value reactor pool and the physics laboratory: 83 Bq m⁻³.

CONCLUSIONS

- The control of radon exposition is of prime importance for radioactive and nuclear workplaces, since they offers a higher risk of radiation exposition by the very nature of the activity.
- Radon concentrations were measured in radiochemical and radiometric laboratories, in the hall of the reactor pool, and in a physics laboratory installed in the same building of the IEA-R1 reactor at CERPq using an active alpha particle detector (RAD7) and the passive CR-39 detector.
- Mean concentration values were in the range of 31 to 51 Bq m⁻³, with RAD7 measurements and 52 to 103 Bq m⁻³, with CR-39 measurements.
- All values are in the limits stablished by WHO, ICRP, Health and Safety Executive - United Kingdom and Other countries for dwellings and workplaces.
- These concentrations are in the same range as the ones observed for dwelling and non-radioactive and non-nuclear workplaces and are lower than the concentrations that can be found in underground and caves.
- The annual effective doses are in the range of 0.31 to 0.72 mSv, being the higher observed values almost 50% of the worldwide effective dose due to radon inhalation.



*Thank you
Obrigado
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