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Indoor radon and ambient equivalent dose rate measurements using a locally manufactured low-cost smart electronic device and validation with reference instrument

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Presentation plan

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INTRODUCTION

The devices for ambient equivalent dose rate H*(10) and radon monitoring are essential for radiation protection in buildings and work places. Unfortunately in Africa, we have difficulties linked to :

- The high cost of measuring devices ;
- The process of acquiring and transporting these devices;
- Handling and maintenance of newly acquired devices .

Nowadays, thanks to scientific and technological expansion, we can produce portable measuring devices that integrate the Internet of Things (IoT) allowing them to be virtually connected to communication tools, such as smartphones and computers.

OBJECTIVES

The objective was to :

- Design efficient and autonomous IoT survey meter based on detector and microcontroller ;
- Carry out real-time ionizing radiation monitoring based on the developed device ;

SPECIFIC OBJECTIVES

- Use less expensive electronic components;
- Realize less complex devices with IoT operation;
- Make comparative analyzes of the developed devices with reference devices.

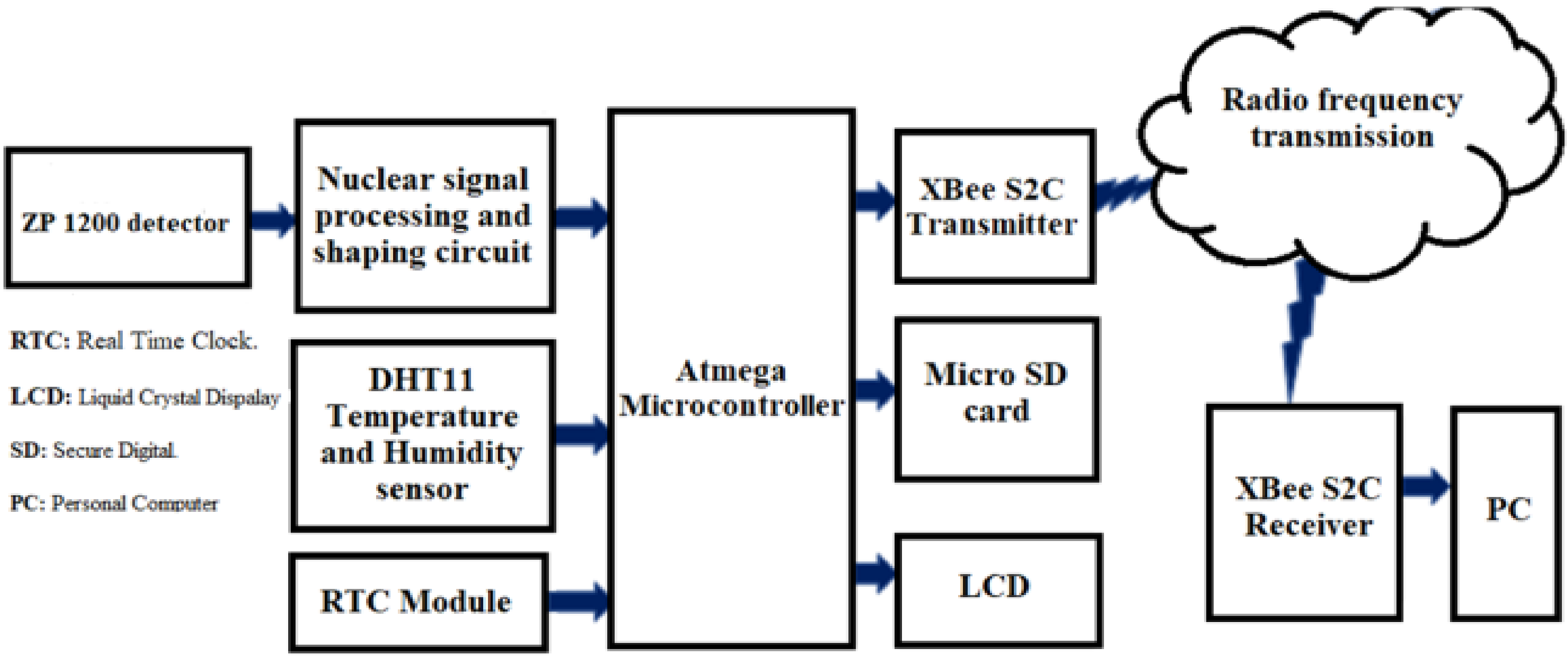
MATERIAL AND METHODS

The developed devices are based on :

- Atmega microcontroller ;
- Geiger-Müller counter ;
- Nuclear analog signal processing and shaping circuit ;
- Real-time display system ;
- Digital data storage module;
- An XBee transmitter for data transmission to a remote PC.

MATERIAL AND METHODS

❖ *Block diagram of the developed survey meter*



MATERIAL AND METHODS

❖ *Detectors and electronic components*

ZP 1200 Geiger-Müller (γ et X)

The **ZP 1200** counter is an ambient dose equivalent-energy compensated GM tube :

- Detects gamma and X-rays
- Energies ranging from 50 keV to 1.25 MeV
- Dose rate measurement range of 0.01 to 100,000 mSv/h
- Response time estimated to be 2.5 seconds.
- Conversion factor (CF) is 0.00667 µSv/h/cpm

J305βɤ Geiger-Müller

The **J305*βγ*** type Geiger-Müller counter :

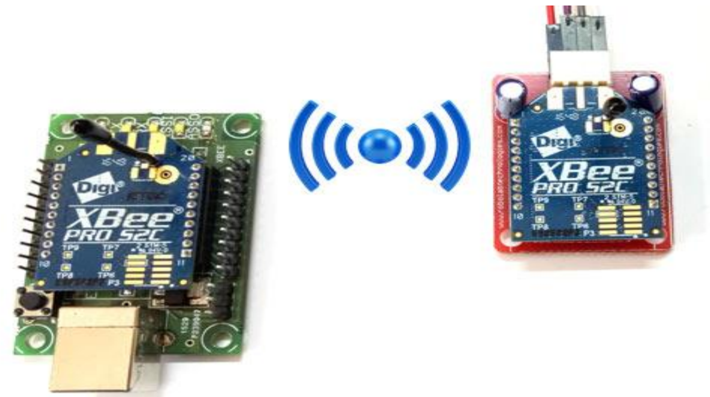
- Detects β and γ radiations ;
- γ sensitivity (Sievert equivalent) of 108 CPM/(µSv/h);
- Maximum CPM of 30000 ;
- Conversion Factor of 0.00812µSv/h/cpm.

MATERIAL AND METHODS

❖ *Detectors and electronic components*

Analog signal processing and shaping circuit

XBEE modules
(Transmitter – Receiver with a range of 1.2 km)



Atmega 328 microcontroller

Number of pins : 28 dont 6 PWM

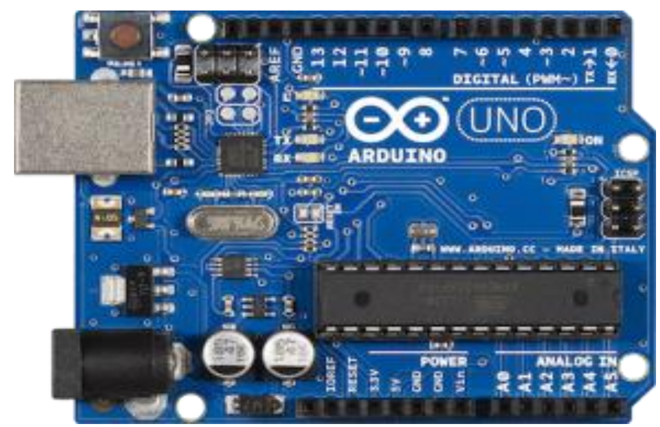
Flash memory : 32 ko

RAM memory : 2 ko

Parallel Ports : 3, with 23 I/O pins

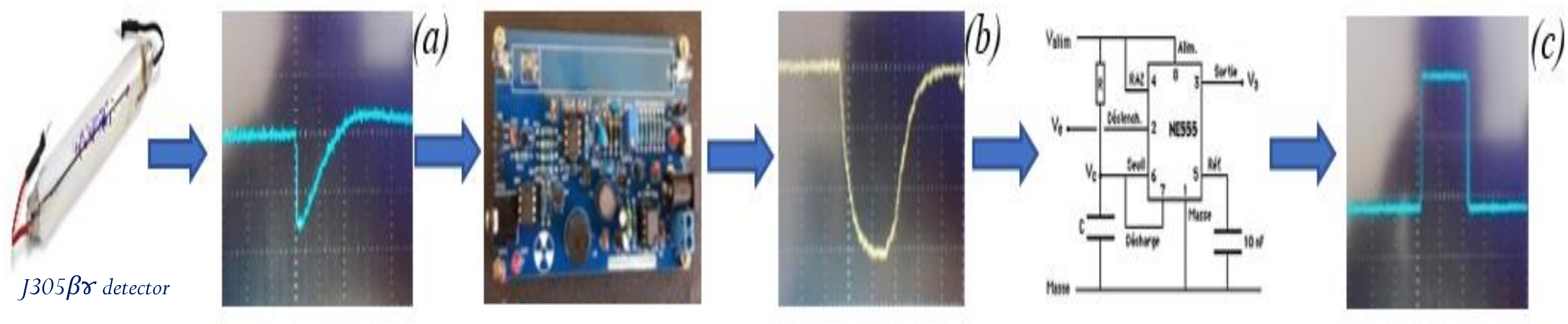
Clock frequency : 16 Mhz (maximum tolerated = 20 Mhz)

6 x 10-bit Analog/Digital converters.



MATERIAL AND METHODS

❖ ***Signal processing and shaping process of the devices***



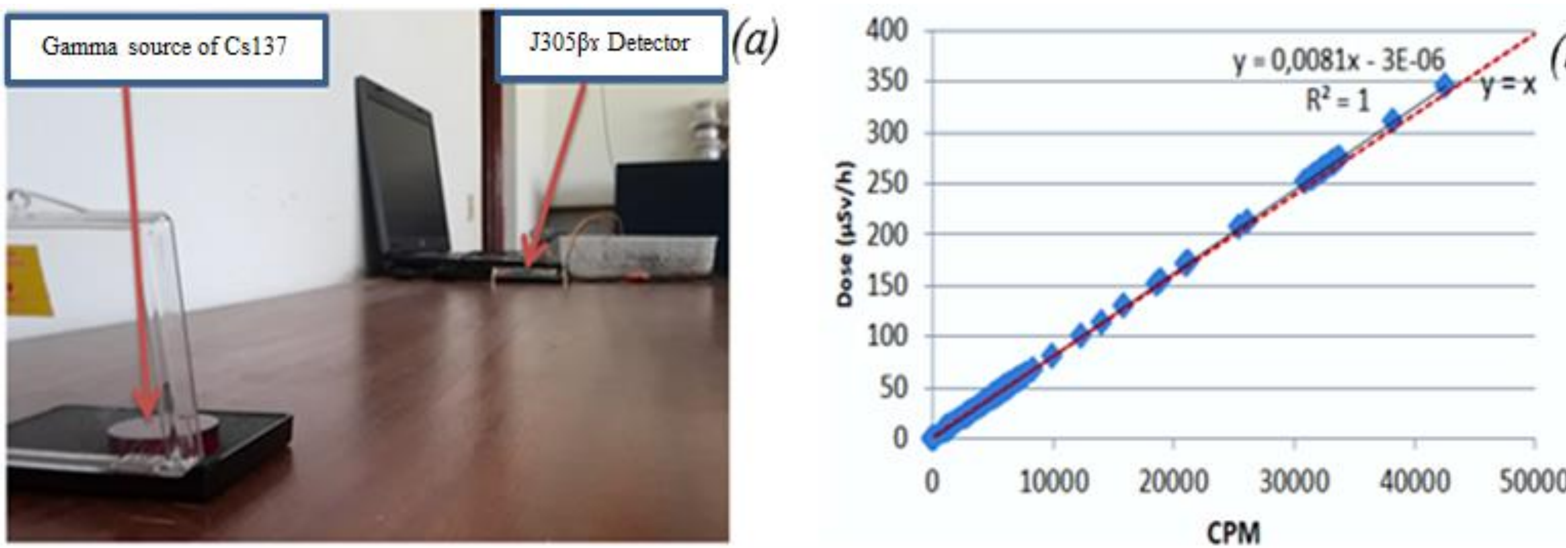
Positive pulse signal of duration t:

$$t = R * C * \ln(3) \qquad (1)$$

MATERIAL AND METHODS

❖ *Calibration procedure of the devices*

The calibration of detectors was carried out in the presence of Cs-137 of 661.6 keV electromagnetic radiation.



$$\text{Dose rate} = \textit{Conversion Factor}\ (CF)\ x\ \textit{Count Per Minute}\ (cpm) \quad (2)$$

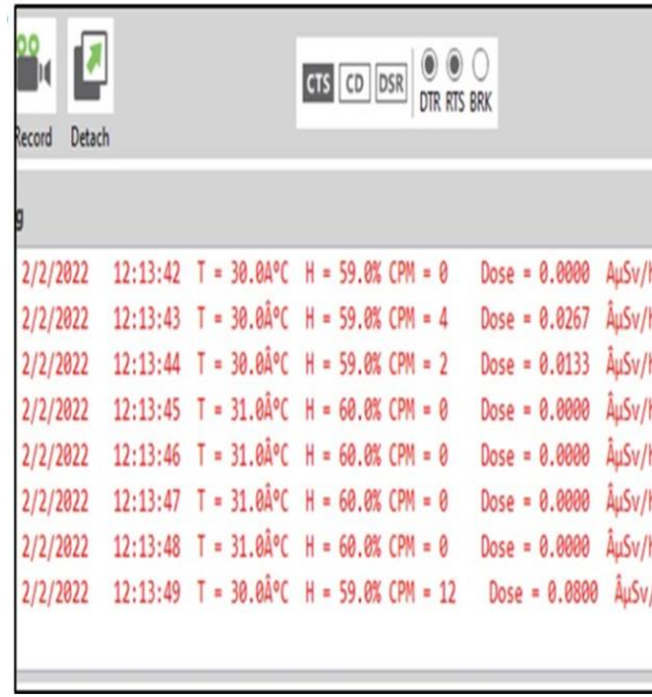
CF = 0.0081 µSv/h/cpm, close to that of the manufacturer : 0.00812 µSv/h/cpm

ACHIEVEMENTS AND APPLICATIONS

❖ *The developed survey meter*

(a) Developed device,
(b) A view of the remote-controller PC

(a)



(b)

The radon reference instrument used

MATERIAL AND METHODS

The device is used to measure ambient equivalent dose rate and radon. Although radon is an alpha emitter and can not be monitored directly with the ZP 1200 detector, gamma rays are also emitted when radon and its short half-life daughters decay. By measuring the level of this gamma radiation, the level of radon can be determined (*Eq. 3*) using specific conversion coefficients (table).

$$\text{Activity concentration}\left(\frac{\text{Bq}}{\text{m}^3}\right) = \text{Mesured value}\left(\frac{\mu\text{Sv}}{\text{h}}\right) \times \text{Corresponding conversion coefficient}\left(\frac{\text{Bq}}{\text{m}^3} \times \left(\frac{\mu\text{Sv}}{\text{h}}\right)^{-1}\right) \quad (3)$$

Conversion coefficients of ambient dose equivalent ($\mu Sv/h$) into radon activity concentration (Bq/m^3) [a-d]

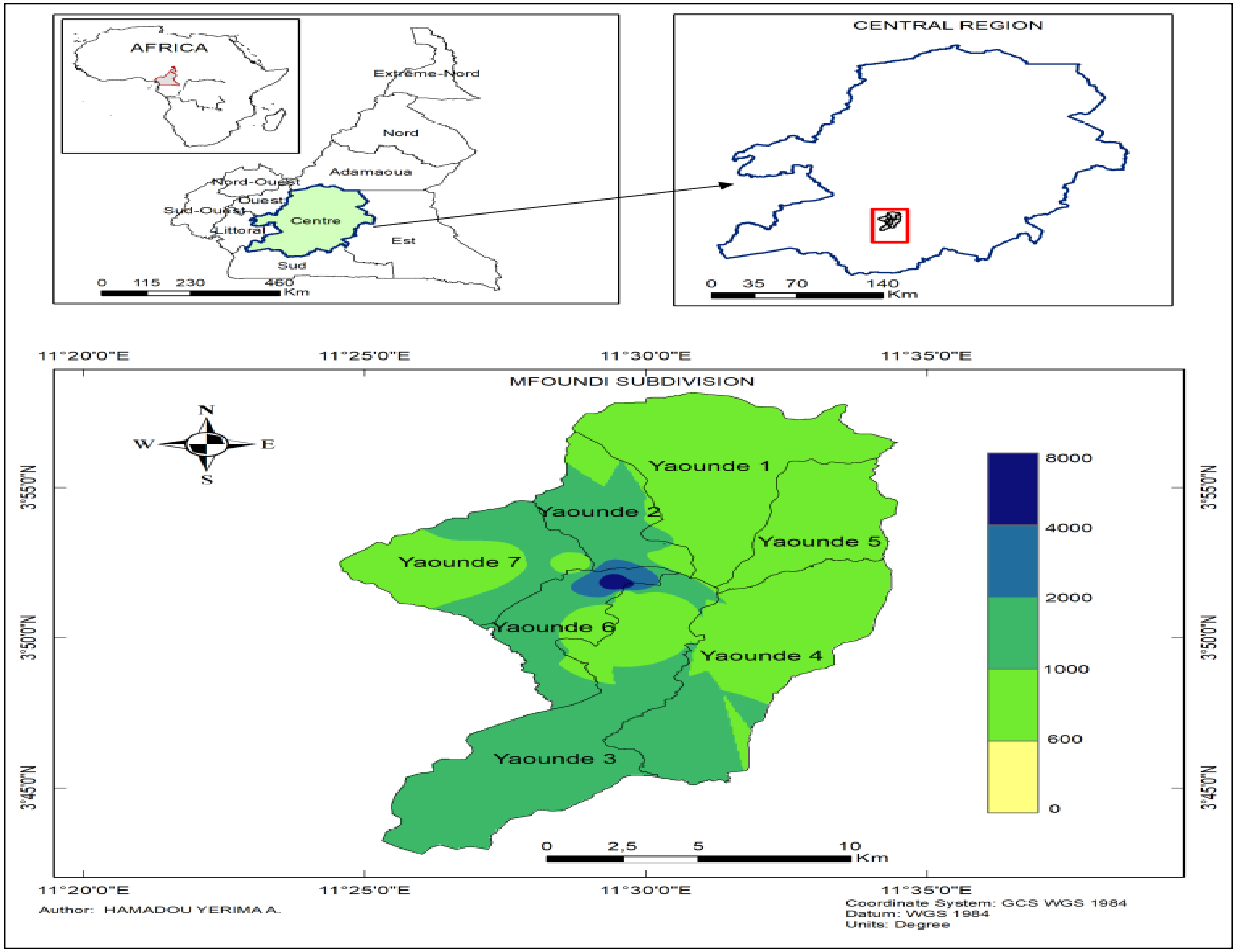
Range of measured value (μSv/h^{-1})	Conversion coefficient (Bq/m^3./(μSv/h))	Range of activity concentration (Bq/m^3)
From 0.01 to 0.10	5500	From 55 to 550
From 0.11 to 0.33	6700	From 737 to 2211
From 0.34 to 0.60	7800	From 2652 to 4680
From 0.61 to 1.00	8400	From 5152 to 8400
From 1.01 to 3.50	8700	From 8787 to 30450
From 3.51 to …	8900	From 31239 to …

a-**Meric, I. et al, 2011**; b-**Zábori, B. et al, 2016**; c-**Andersson, S. 2010**; d- **Vagle, O. et al, 2007**

ACHIEVEMENTS AND APPLICATIONS

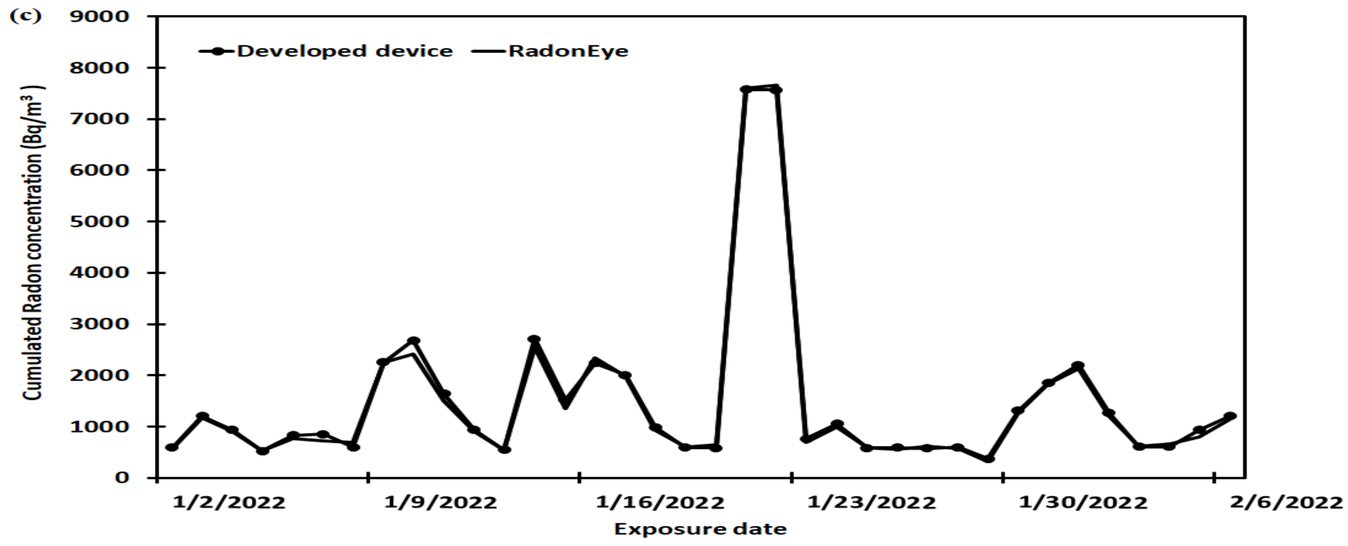
In 2022, measurement campaigns of indoor ambient equivalent dose rate H*(10) and radon tracing were carried out in Yaoundé city, Cameroon.

Location map of measurement points and concentration distribution

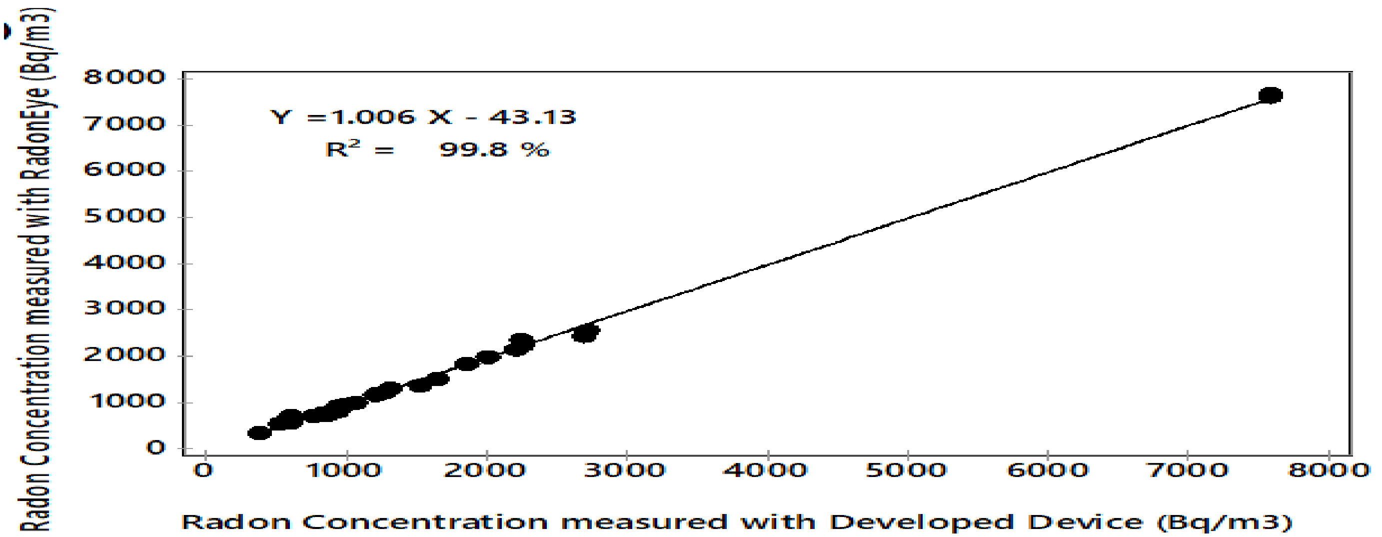


ACHIEVEMENTS AND APPLICATIONS

Cumulated radon concentration of both devices



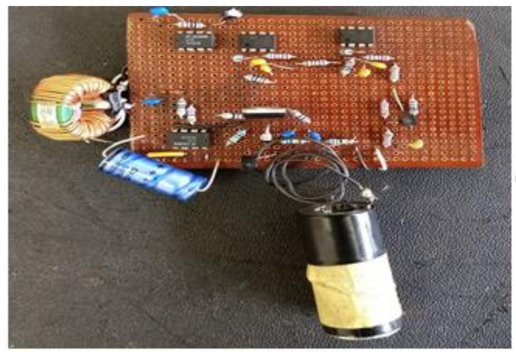
Linear regression between radon concentration of the two devices



ACHIEVEMENTS AND APPLICATIONS

We developed another survey meter associated with an unmanned aerial vehicle for ionizing radiation detection at altitude. Campaigns to measure the ambient equivalent dose rate H*(10) across certain cities in Cameroon were carried out from 2022 to 2023.

Survey meter associated with the drone for altitude measurements



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CONCLUSION

The two presented devices for ambient equivalent dose rate H*(10) and radon measurement, show promising results for the future of environmental radioactivity monitoring in Africa because the developed devices are :

- Simple, effective ;
- Autonomous, portable ;
- Low-cost and easy to manufacture.

Development and applications of these devices have been published in peer-reviewed journals.

PUBLICATIONS

[1] **Jacob Mbarndouka Taamté**, Saïdou, Bodo Bertrand, Kountchou Noubé Michaux, Folifack Signing Vitrice Ruben,Younui Susan Yakum-Ntaw, Hamadou Yerima Abba, Chonlagarn Iamsumang, Charles Massey "*Low-cost wireless smart device design for radiation protection and nuclear security*", **Journal of Instrumentation**, https://doi.org/10.1088/1748-0221/16/06/T06011 , **2021** (***IOP***).

[2] **Jacob Mbarndouka Taamté,** Koyang François, Gondji Dieu Souffit, Oumar Bobbo Modibo, Hamadou Yerima Abba, Kountchou Noubé Michaux, Saïdou, Shinji Tokonami, **"***Low-cost radon monitoring with validation by a reference instrument***", Instrumentation Science and Technology**, **2022** **https://doi.org/10.1080/10739149.2022.2095401** (***Taylor and Francis***).

[3] Vitrice Ruben Folifack Signing, **Jacob Mbarndouka Taamté,** Michaux Kountchou Noube, Zacharie Stève Omgba Abanda, Hamadou Yerima Abba, Saïdou "Real-time environmental radiation monitoring based on locally developed low-cost device and unmanned aerial vehicle", **Journal of Instrumentation**, 18 P05031, https://doi.org/10.1088/1748-0221/18/05/P05031, **2023** (***IOPscience***).

SOME AWARDS

CERTIFICATE
OF ACHIEVEMENT

Best
AWARD
2022

THIS CERTIFICATE
IS PROUDLY PRESENTED TO

MBARNDOUKA TAAMTE Jacob

FOR WINNING THE BEST
YOUNG SCIENTIST AND RADIATION PROTECTION PROFESSIONAL AWARD
at 6th African Congress of the International Radiation Protection Association (IRPA)

Held in Accra, Ghana on 10 - 13 October, 2022

Prof. Joseph K. Amoako
Chairman
Local Organizing Committee

IRPA

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Accra - Ghana

Dr. Bernard Le Guen
President
IRPA

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