3rd BIENNIAL AFRICAN CONFERENCE ON FUNDAMENTAL AND APPLIED PHYSICS 2023(ACP2023)

Zigbee-based wireless smart device for enclosed space real-time air quality monitoring: Experiment, data analysis and risk assessment

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Plan de Présentation

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INTRODUCTION

Air pollutant measuring devices are essential for monitoring air quality in buildings and public spaces. Unfortunately in Africa, we have difficulties related to the :

- ❖ High cost of these measuring devices ;
- ❖ Process of acquiring and transporting devices;
- ❖ Handling and maintenance of newly acquired devices.

Nowadays, thanks to the technological evolution, we can realize portable measuring devices, which integrate the Internet of Things (IoT) and can connect virtually to communication tools, such as smartphones and computers.

OBJECTIVES

- ❑ Design an intelligent, efficient and autonomous device based on sensors and microcontrollers for measuring air pollutants;
- ❑ Carry out real-time monitoring of air quality based on the developed device.

SPECIFIC OBJECTIVES

- ❑ Use less expensive sensors and electronic components ;
- ❑ Build less complex IoT-enabled devices ;
- ❑ Carry out calibration work and comparative analyzes of the results obtained with the reference values (WHO).

MATERIAL AND METHODS

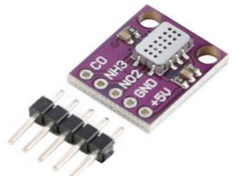
The developed device is based on the components such as :

- Atmega Microcontrollers ;
- Sensors and electronic components ;
- A real-time display screen ;
- A digital data storage module ;
- Two XBee transceiver modules for wireless data transmission to a remote PC.

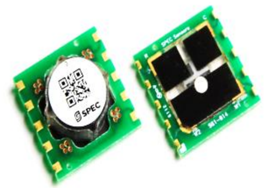
MATERIAL AND METHODS

❖ *Electronic components used*

O_3 Sensor (MQ131)



CO and NO_2 Sensor (CJMCU-6814)

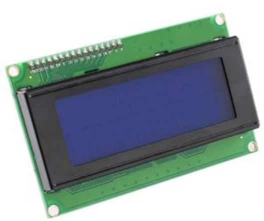


SO_2 Sensor (SPEC sensor)

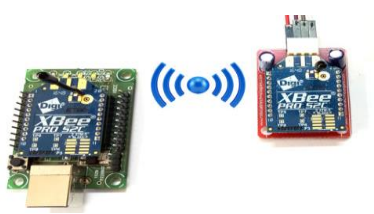
Particle matter sensor (PPD42NS)

Temperature and humidity sensor (DHT22)

- Number of pins: 28 including 6 PWM Mémoire Flash : 32 ko
- RAM memory: 2 KB
- Parallel ports: 3, with 23 I/O pins
- Clock frequency: 16 Mhz (max tolerated = 20 Mhz)
- 6 10-bit Analog/Digital converters.



20x4 LCD screen



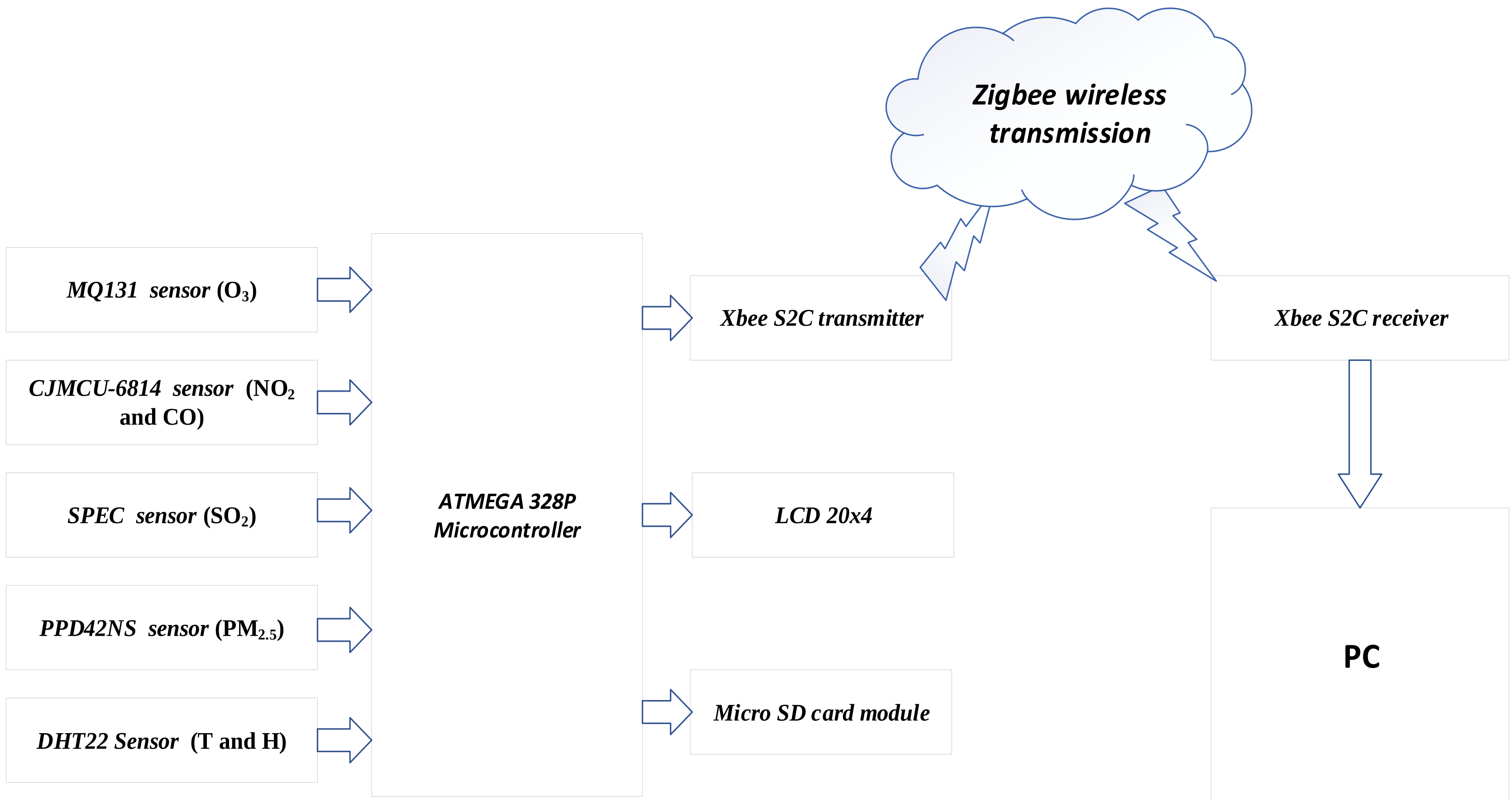
XBEE Modules (Transmitter - Receiver)

SD card support

Real-Time Clock

MATERIAL AND METHODS

❖ *Synoptic diagram of the device developed*



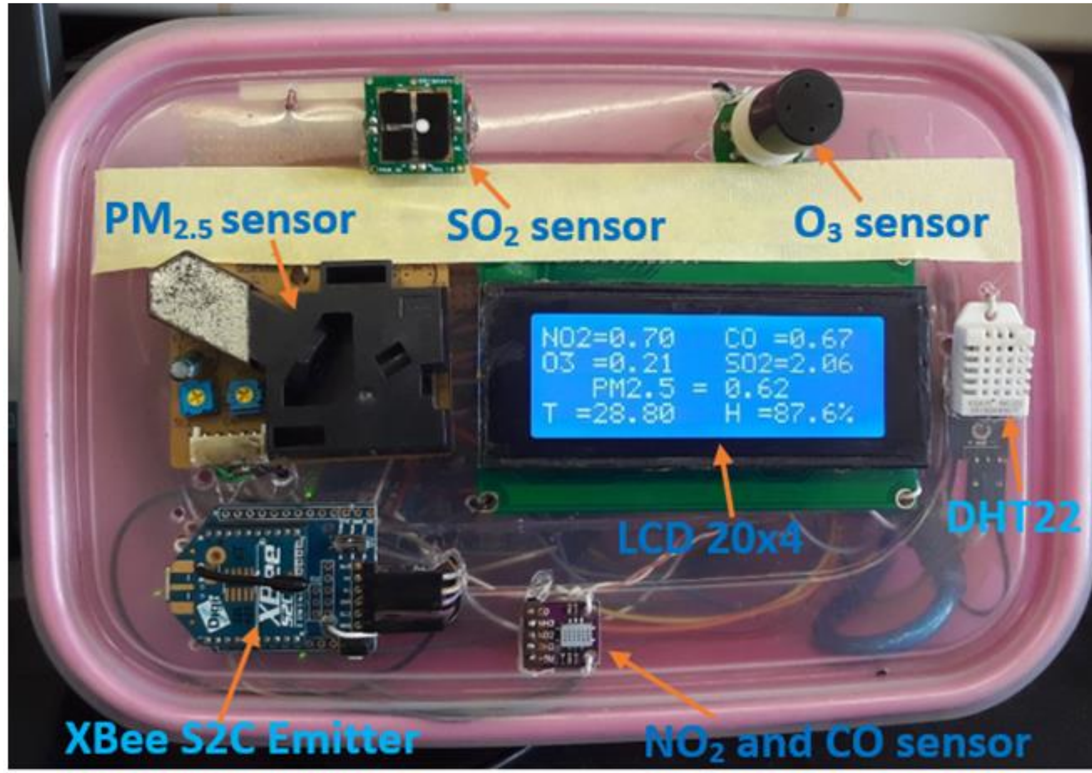
MATERIAL AND METHODS

❖ ***Design and realization process of the electronic prototype***

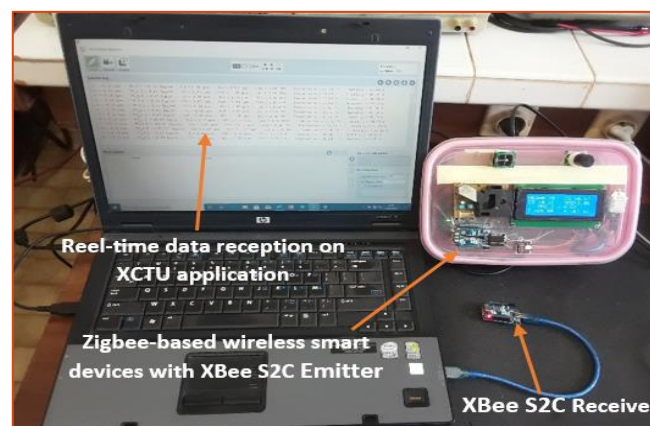
- Purchasing components, sensor configuration tests;
- Individual programming and functional testing of each sensor and other component used;
- Assembly of the prototype developed following the proposed block diagram;
- Programming the general operation of the device and calibration work.

MATERIAL AND METHODS

Air quality monitoring device based on IoT

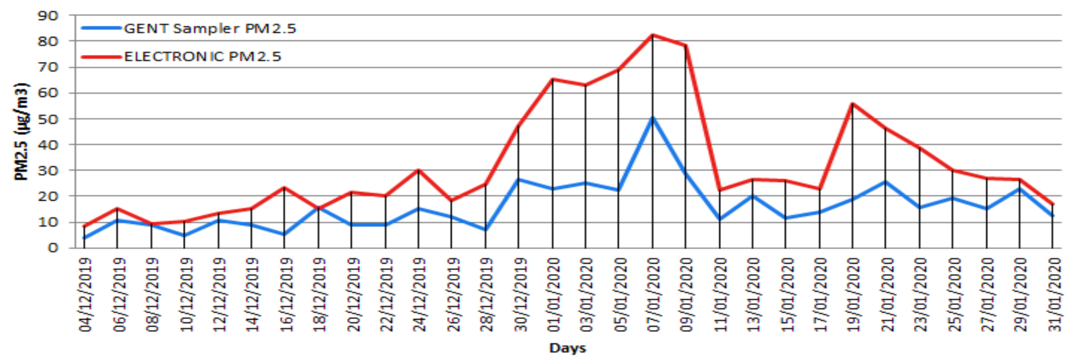


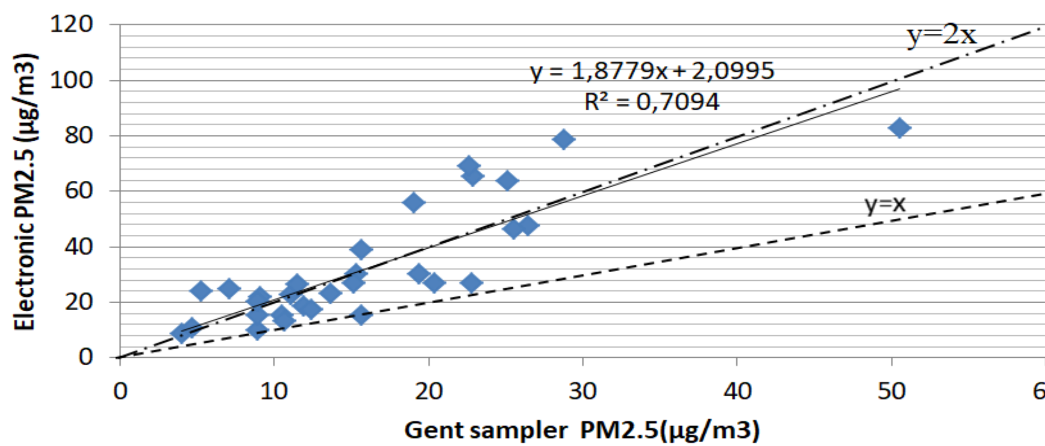
Wireless data transmission by ZigBee modules



MATERIAL AND METHODS

❖ ***Calibration work of the electronic device with a reference device: the Gent Sampler***





MATERIAL AND METHODS

❖ *Calibration work of the electronic device with a reference device: the Gent Sampler*

The regression line with equation y = 1.8779x + 2.0995, and the line with equation y = 2x are almost coincident in the scatter plot. Thus, the data from the electronic device can be correlated with that of the GENT Sampler in the following way:

$$Electronic\ PM = 1.8779 * GENT\ PM + 2.0995 \approx 2 * GENT\ PM \quad (1)$$

It has been demonstrated by Castanho et al., that the Gent Sampler determines a daily concentration, estimated at 50% of normal pollution. The electronic device will be in agreement with the GENT Sampler if the following relation deduced from Eq. (1), is respected:

$$(Electronic\ PM - GENT\ PM) / GENT\ PM \approx 1 \quad (2)$$

Measuring period: 2 months		
Devices	GENT Sampler	Electronic device
$PM_{2.5}$ Average concentration ($\mu g/m^3$)	16.12±0.11	32.37±0.40

Using equation (2) and the values obtained in the table, a reliability coefficient of 1.00 ± 0.01 is obtained.

MATERIAL AND METHODS

❖ *Air quality assessment method*

The World Health Organization (WHO) : CO, O_3, SO_2, NO_2 et $PM_{2,5}$ / PM_{10}

WHO reference values for air quality (indoor and outdoor)

Pollutants	WHO guideline values	Health effects
Particles with a diameter less than 2,5 µm $PM_{2.5}$)	15 µg/m³ daily average 5 µg/m³ annual average	Risks of developing cardiovascular and respiratory diseases
Ozone (O_3)	100 µg/m³ on average over 8 hours	May induce breathing difficulties, asthma. Risk of disruption of the functioning of the lungs
Nitrogen dioxide (NO_2)	10 µg/m³ annual average 25 µg/m³ hourly average	Risk of development of chronic bronchitis in asthmatic subjects.
Sulphur dioxide (SO_2)	40 µg/m³ daily average	May cause respiratory and pulmonary system function and eye irritation
Carbon monoxide (CO)	60 µg/m³ daily average	Asphyxiant gas that attaches to red blood cells and prevents them from carrying oxygen properly in the body

MATERIAL AND METHODS

❖ *Air quality and exposure risks assessment methods*

Air quality assessment

IQA sub-index = (measure / reference value) x 50 (3)

Air Quality Index (AQI)

AQI Values	Levels of Health Concern
From 0 to 50	Good
From 51 to 100	Moderate
From 101 to 150	Unhealthy for Sensitive Groups
From 151 to 200	Unhealthy
From 201 to 300	Very Unhealthy
From 301 to 500	Hazardous

Exposure risks assessment

Air Quality Health Index (AQHI)

$$AQHI_{2.5} = \frac{10}{10.4} * \left[100 * ((e^{0.000871*NO_2} - 1) + (e^{0.000537*O_3} - 1) + (e^{0.000487*PM_{2.5}} - 1))\right] \quad (4)$$

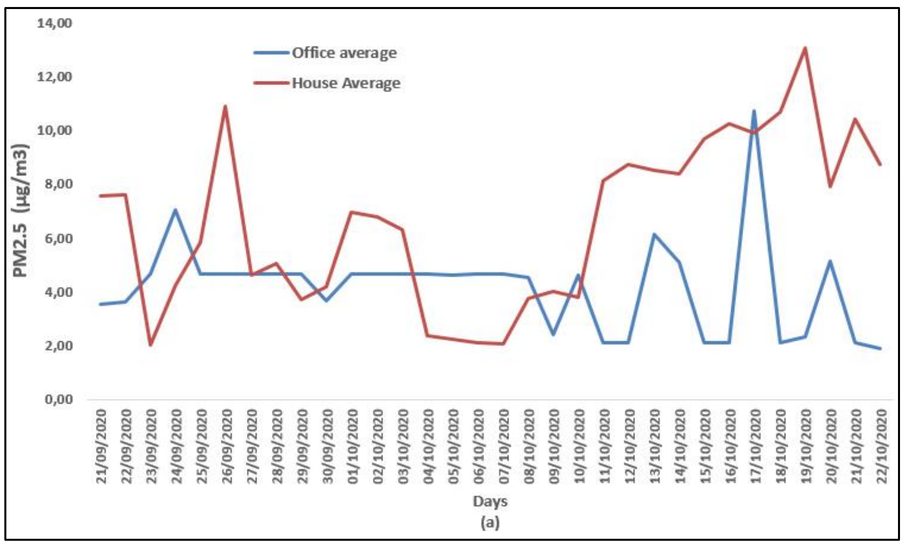
With NO_2 and O_3 measured in ppb (parts per billion) and $PM_{2.5}$ measured in µg/m^3

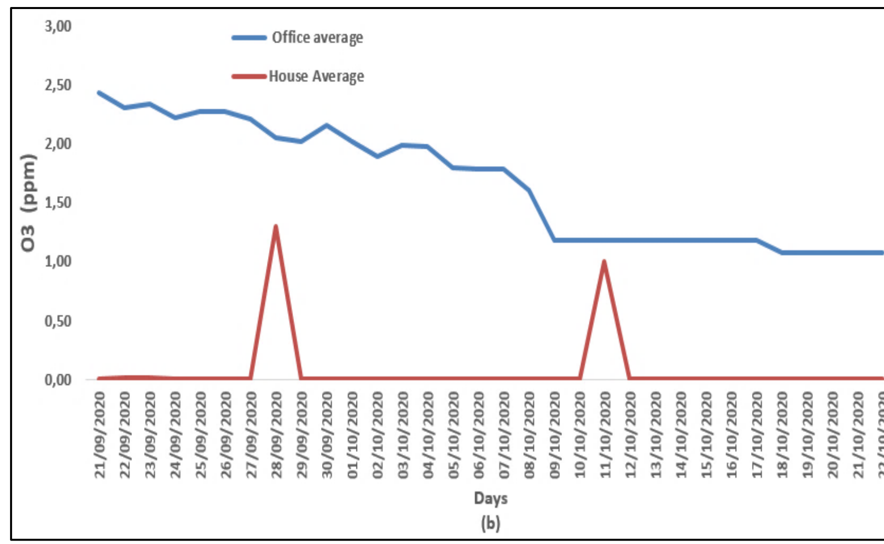
Helth Risk Category	LOW	MODERATE	HIGH	VERY HIGH	SERIOUS
$AQHI_{2.5}$ / $AQHI_{10}$	From 0 to 3	From 4 to 6	To 7	From 8 to 10	Beyond 10

APPLICATIONS

This device was produced in two copies and used at the same time from September to October 2020, for the measurement of air quality in two localities of the city of Yaoundé, Cameroon (administrative office and family home).

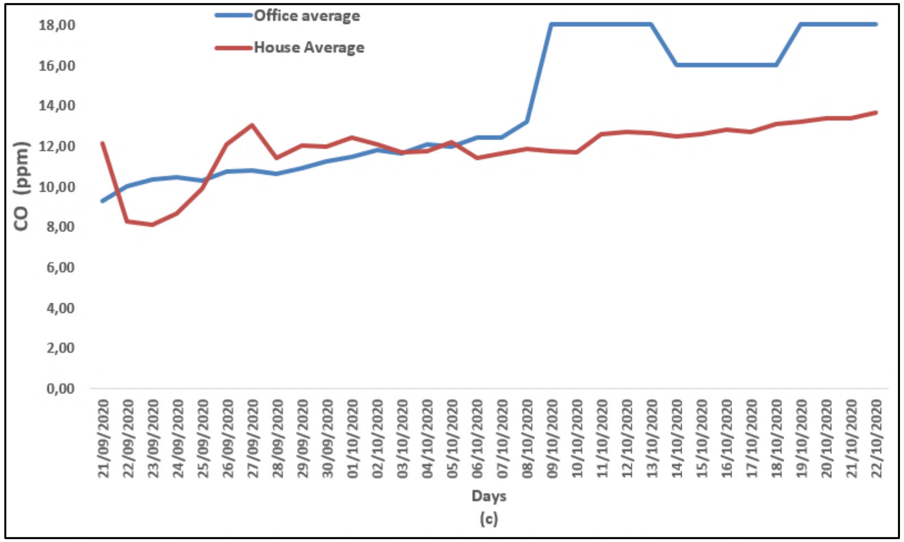
- ***Temporal evolution of the average concentrations of the pollutants measured***

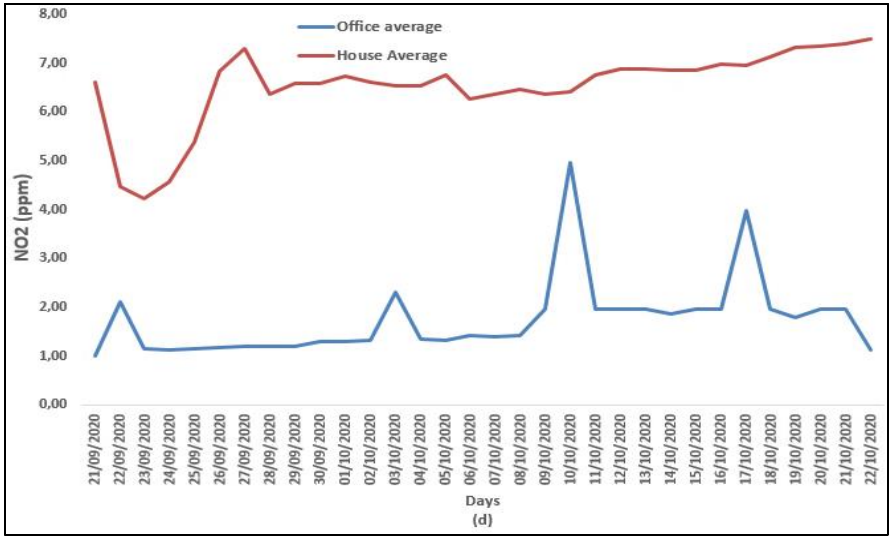


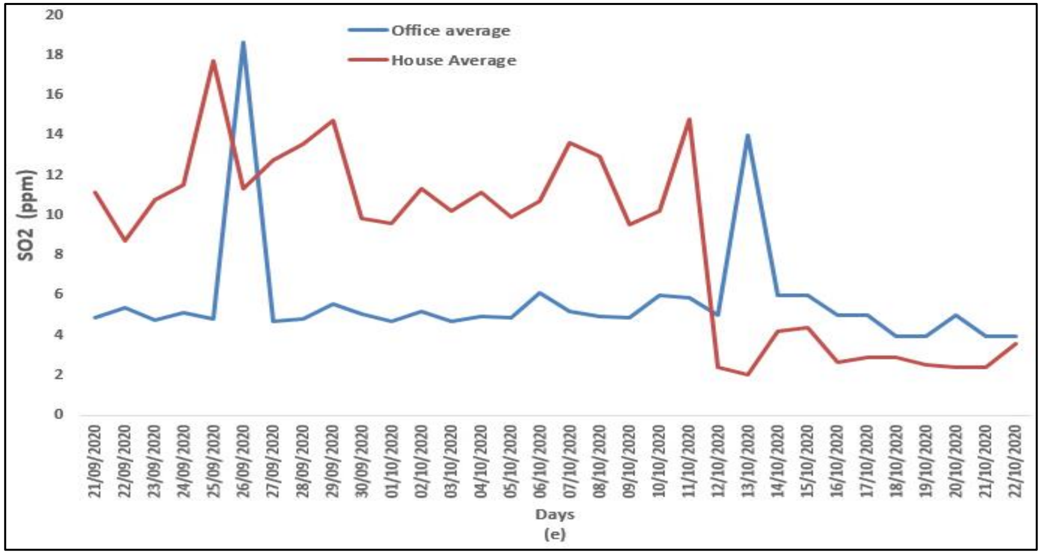


APPLICATIONS

❖ *Temporal evolution of the average concentrations of the pollutants measured*







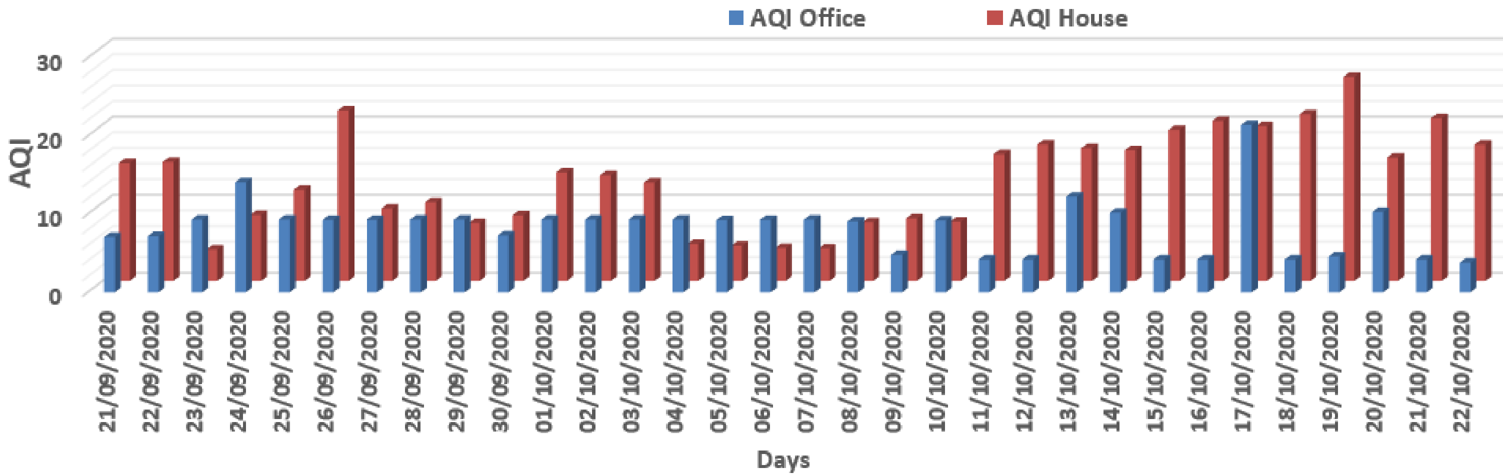
APPLICATIONS

❖ ***Statistical data of the periodic average concentrations of the pollutants measured***

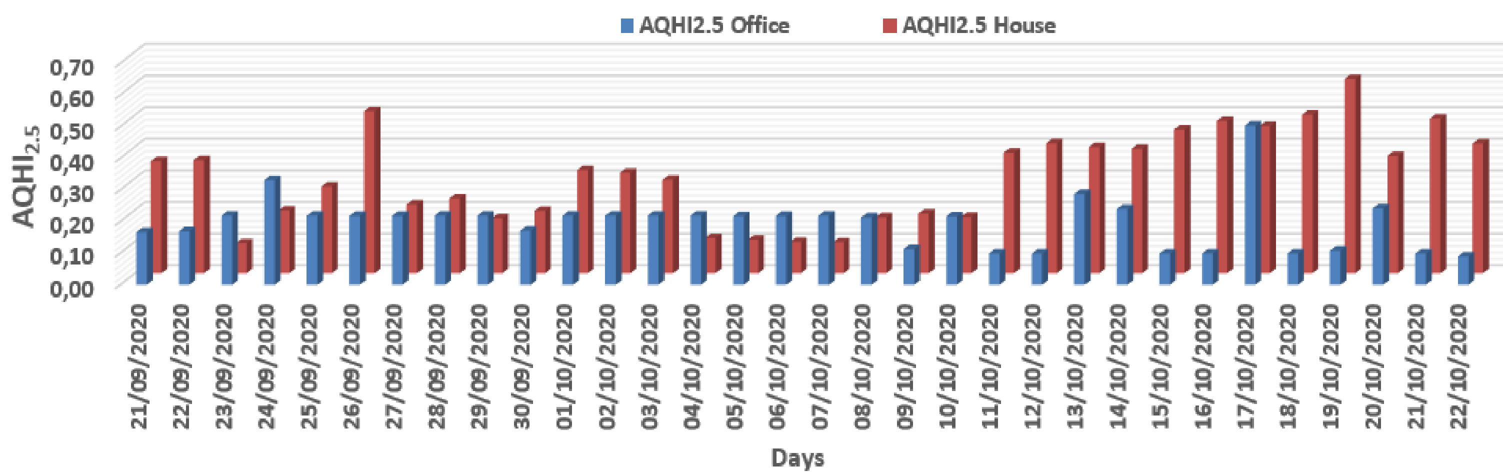
Pollutants	**Office**	**House**
$PM_{2.5}$ Average (µg/m^3) [*Min-Max*]	**4.17** ± 1.78 [*1.9-10.71*]	**6.57** ± 3.08 [*2.01-13.06*]
O_3 Average (ppm) [*Min-Max*]	**1.65** ± 0.49 [*1.07-2.42*]	**0.07** ± 0.28 [*00-1.30*]
CO Average (ppm) [*Min-Max*]	**13.88** ± 3.23 [*9.27-18.03*]	**11.91** ± 1.37 [*8.11-13.66*]
NO_2 Average (ppm) [*Min-Max*]	**1.74** ± 0.81 [*1.01-4.97*]	**6.52** ± 0.80 [*4.22-7.49*]
SO_2 Average (ppm) [*Min-Max*]	**5.71** ± 2.90 [*3.98-18.65*]	**8.69** ± 4.61 [*2.04-17.72*]

APPLICATIONS

❖ *Daily evolution of the AQI values in the two environments*



❖ *Daily evolution of the AQHI2.5 values in the two environments*



APPLICATIONS

❖ *Exposure risk assessment from September to October 2020*

Air Quality Index (AQI)			Air Quality Health Index ($AQHI_{2.5}$)		
Office AQI Averages [Min-Max]	House AQI Averages [Min-Max]	Levels of Health Concern	Office $AQHI_{2.5}$ Averages [Min-Max]	House $AQHI_{2.5}$ Averages [Min-Max]	Levels of Health Concern
8.36 ± 3.56 [3.80-21.42]	13.14 ± 6.17 [4.02-26.12]	**Good**	0.20 ± 0.08 [0.09-0.50]	0.31 ± 0,14 [0.09-0.61]	**Low risk**

CONCLUSION

The air pollutant measuring device presented shows promising results for the future of air quality monitoring in Africa because its development is in line with the socio-economic contexts of the continent, namely :

- ❖ Easy to make, Simple, effective ;
- ❖ Autonomous, portable and ;
- ❖ Low-cost (less than 100 €).

Local development and use of several other measuring devices have been carried out and published in high-impact peer-reviewed journals.

PUBLICATIONS

[1] **Mbarndouka Taamté Jacob**, Kountchou Noubé Michaux, Bodo Bertrand, Tchuente Siaka Yvette Flore, Nducol Nasser, Folifack Signing Vitrice Ruben, Tagne Mogue Ruth Line, Saïdou "*Low-cost air quality monitoring system design and comparative analysis with a conventional method*", International Journal of Energy and Environmental Engineering, https://doi.org/10.1007/s40095-021-00415-y, **2021** (***Springer***).

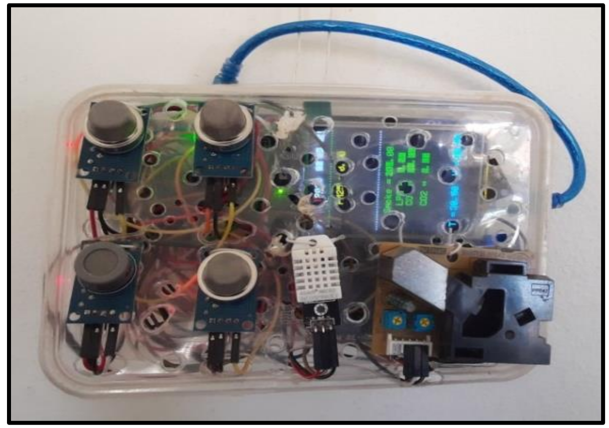
[2] **Mbarndouka Taamté Jacob**, Nducol Nassera, Kountchou Noubé Michaux, Tchuente Siaka Yvette Flore, Saïdoua, "*Zigbee-based wireless smart device for enclosed space real-time air quality monitoring: experiment, data analysis and risk assessment*", Ebook : Indoor Air Quality Assessment for Smart Environments, doi.10.3233/AISE220005, (***IOS Press Book***) **2022**.

[3] **Mbarndouka Taamté Jacob**, Folifack Signing, V.R., Kountchou N.M., Bodo, B., Saïdou "*An efficient environmental monitoring data encryption algorithm based on DNA coding and hyperchaotic system*", International Journal of Information Technology, https://doi.org/10.1007/s41870-022-00887-z, (***Springer***) **2022**.

OTHERS

❖ *Air quality measuring devices*

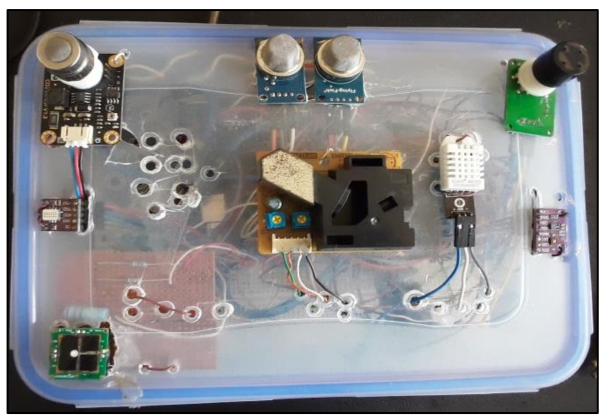
Zigbee based IoT device (PM2.5, CO, CO2, NO2, VOC and CH4)



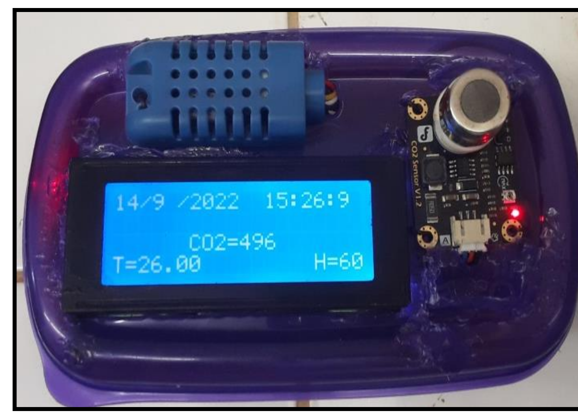
GPRS based IoT device (CO, CO2, PM2.5, GPL and Smoke)

IoT device based on Thingspeak cloud (PM2.5, PM10)

CO2 measuring device



Air pollutant measurement device



CO2 measuring device

SOME AWARDS

ap sa

Fondation Daniel Iagolnitzer

Prix de finaliste

décerné par

L'Association pour la Promotion de la Science en Afrique (APSA)

à

M. MBARNDOUKA TAAMTE Jacob, finaliste du Concours APSA

« Challenge Physique expérimentale Afrique 2019 »

pour sa réalisation d'un dispositif de détection des polluants atmosphériques via la technique Internet des Objets.

Yaoundé, le 27 novembre 2019.

Vincent Rivasseau

Président de l'APSA

Finalist Prize awarded by the Association for the Promotion of Science in Africa (APSA)

SOME AWARDS


CAMEROON ACADEMY OF SCIENCES
ACADÉMIE DES SCIENCES DU CAMEROUN
Science-Excellence-Progress

Prix d'encouragement

décerné par

L'Académie des Sciences du Cameroun

à

M. MBARNDOUKA TAAMTE Jacob, finaliste du Concours APSA

Challenge Physique expérimentale Afrique 2019

pour sa réalisation d'un dispositif de détection des polluants atmosphériques via la technique Internet des Objets et qui lui a valu d'être finaliste de ce concours.
L'Académie des Sciences du Cameroun l'encourage à poursuivre ses efforts pour le développement de la physique expérimentale.

Yaoundé, le 27 novembre 2019.

Président de l'Académie des sciences du Cameroun

Encouragement prize awarded by the Academy of Sciences of Cameroon

SOME AWARDS

MINISTÈRE DE LA RECHERCHE SCIENTIFIQUE ET DE L'INNOVATION

MINISTRY OF SCIENTIFIC RESEARCH AND INNOVATION

Journées d'**E**xcellence de la **R**echerche **S**cientifique et de l'**I**nnovation au **C**ameroun

(JERSIC), Septième Edition

PRIX DE L'INNOVATION
EN FAVEUR DE LA JEUNESSE

Déceré à l'**Equipe MBARNDOUKA TAAMTE Jacob (IRGM),**
pour ses travaux de recherche présentés à l'occasion de la Septième Edition des JERSIC qui se sont déroulées à Yaoundé du 27 au 29 octobre 2021, sous le thème ***«Recherche Scientifique, levier de la transformation structurelle de l'économie du Cameroun en contexte de la pandémie de la COVID-19»***.

Fait à Yaoundé, le 01 NOV 2021

LE MINISTRE DE LA RECHERCHE SCIENTIFIQUE ET DE L'INNOVATION

Pr Madeleine Tchuinte

Youth innovation prize awarded by the Ministry of Scientific Research and Innovation of Cameroon

Dr Jacob Mbarndouka Taamté, Research Officer and PhD in Electronics, Electrical Engineering, Automation and instrumentation, Research Centre for Nuclear Science and Technology (CRSTN), Institute of Geological and Mining Research (IRGM), *Tel: (+237) 679598815,* *mtjfirst@yahoo.fr* / *taamtej@gmail.com* / *jacob.mbarndouka@irgm-cameroon.org*

THANK YOU FOR YOUR KIND ATTENTION