PAPER • **OPEN ACCESS**

Monitoring and analysis of air quality for community empowerment in Environmental Health

To cite this article: Cristian Camilo Ordoñez *et al* 2019 *J. Phys.: Conf. Ser.* **1247** 012054

Monitoring and analysis of air quality for community empowerment in Environmental Health

Cristian Camilo Ordoñez, [a*] Jennyfer López, [a] Héctor A. Guañarita, [a] José Armando Ordoñez [a]

[a] *University Foundation of Popayán, Intelligent Management Systems, Popayán Cauca Colombia*

Abstract. The emission of greenhouse gases has increased dramatically. Among these, carbon monoxide (CO) has been identified as having the greatest negative impact on human health. These gases are produced mainly by human activities and, therefore, can be reduced if some community actions are carried out. This type of action is known as community empowerment and can be defined as active Participation of the community to achieve common objectives. The first step for empowerment is to know the magnitude of the problem, however, in the case of environmental monitoring, the price of the monitoring devices can be prohibitive. In this research, an air quality-monitoring platform based on the Internet of Things (IoT) is proposed. This platform uses Low-cost devices such as Arduino and Raspberry to measure the air quality in the center of Popayan city. The information is collected, processed and shared with the community through an app. The early results show an impact in the community perception. Also to the lessons learned, can be used to other low-cost developments.

Keywords: IoT, Carbon monoxide (CO), platform, App.

* **Address correspondence**: Cristian Camilo Ordoñez, University Foundation of Popayán, Popayán, Colombia, +57; Tel 3006519654, cordonezq@unicauca.edu.co.

1. Introduction

Nearly seven million deaths worldwide are caused by contaminated air in the world (cerebrovascular problems, heart disease, lung cancer, among other diseases). This pollution is largely caused by Short-lived greenhouse pollutants emitted from fuel combustion [1]. The first step to reverse this situation is to know the air quality, however in many cities such as Popayán- Colombia, very few measurements are taken during the year due in part to the high costs of the devices used for this purpose. In this paper, a low-cost platform for monitoring air quality based on the Internet of things is presented. Information is processed and analyzed, alerts are generated to users through mobile devices Low-cost devices such as Arduino and Raspberry are integrated as well as various communication protocols.

The rest of this document is organized as follows: section 2 presents the related works, section 3 shows the methodology, section 4 describes Results conclusions and future works.

2. Related works

Kirthima presents a real-time air quality monitoring system that monitors PM 2.5, carbon monoxide, carbon dioxide, temperature, humidity and air pressure in Delhi. This system uses IoT and Raspberry Pi and the collected data were compared with the one provided by authorities [2]. Baklouti et al. present an air quality monitoring system based on real-time crowd detection. Low-cost and low-power devices are used to measured air quality. The collected data are sent to the cloud, processed using R (an open source tool) and displayed in real time on maps [3].

Aslam et al developed an autonomous system to detect smoke, carbon monoxide, and other toxic gases. Gases are monitored and displayed on LCD screens and pop-up alarms are generated when thresholds

IOP Conf. Series: Journal of Physics: Conf. Series **1247** (2019) 012054 doi:10.1088/1742-6596/1247/1/012054

are exceeded. This information is transmitted to the control center through a wireless link. The automatic detection and response system allows a quick reaction in case of an emergency [11]. Kumar et al. developed an Indoor-Air-Quality (IAQ) sensor in conformity with ISO/IEEE/IEC 21451 standards. The developed IAQ sensor is suitable to monitor the concentrations of indoor air quality parameters like PM2.5, CO2, O3, and CO [6]. Anuj Kumar et al, presented a sensor controlled through smart devices using GSM network. Machine-to-machine data communication (M2M) is implemented for the air quality sensor and smart devices. The sensor is portable, easy to operate, low cost and energy efficient [4]. Finally, it is important to highlight the research of Mendez et al. that presents some of the most relevant works in the area of air pollution monitoring in large cities and water monitoring in rural areas. In addition, a solution based on a participatory detection approach is presented to monitor air pollution in large cities [5].

3. Methodology

Design Thinking was used due to the importance of users in community empowerment. The main phases of Design thinking are: I) Empathize to know the problem from the user's perspective. II) Define, seeks to interpret the problem, III) Ideation, stage of creativity to offer solutions. IV) Test prototypes, V) Evaluate the impact obtained [6]. Next, the results of the application of each of the phases are described:

Empathy phase: First of all, a parking lot in the center of the city of Popayan was selected to measure the quality of air. Here, users, workers, and passers-by were interviewed about their knowledge about environmental pollution. Most people didn't know about the risks for human health. Besides, some workers expressed that they often suffer from respiratory problems and frequent headaches.

Definition phase: The main problem was identified: People don't know the real situation on air pollution. It was defined that the application should be easily accessible, and have real-time feedback.

Ideation Phase: members of the team gave possible solutions to this problem, thus giving a joint contribution and collaboration for the construction of a strategy that could be applied. At this stage, it was decided to make an application to inform the carbon monoxide CO level. The graph is updated every 20 seconds and generates alerts every time a threshold is exceeded.

Prototyping phase: this was carried out in two phases, the first, is the data collection through the mq135 sensor and Arduino Uno. In phase two, data were processed using raspberry pi3 and sent data to the cloud. Measurements were made every hour in accordance with Colombian air quality regulations. The threshold for alerts is defined for the Colombian Air Quality Index (AQI), which allowed us to analyze the concentration levels of the main pollutants that influence air quality. Likewise, a mobile application was developed to see the air quality index in real time, the alerts are generated according to the defined ranges and pollutants. The architecture of the system is shown in Fig 1.

IOP Conf. Series: Journal of Physics: Conf. Series **1247** (2019) 012054 doi:10.1088/1742-6596/1247/1/012054

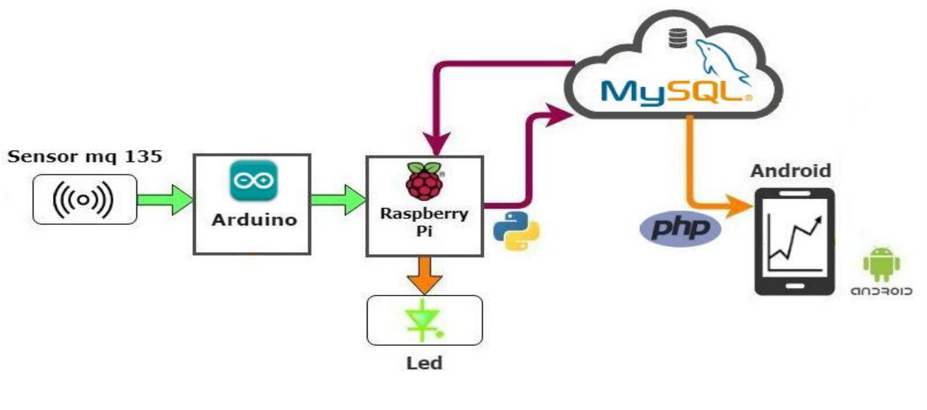


Fig. 1 Architecture of the platform

(a) Sensor mq135

MQ135 sensor requires a 24-hour preheating and a 5v supply, an analog reading was performed to determine the gas concentration in ppm (parts per million). This sensor provides a graph that allows obtaining the gas concentration (See fig 2) [7].

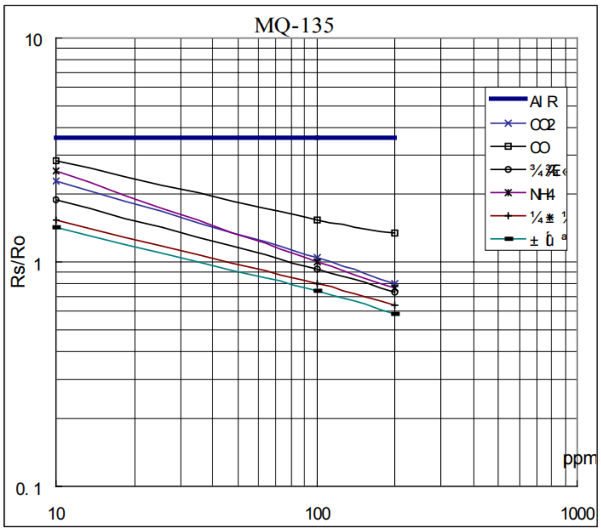
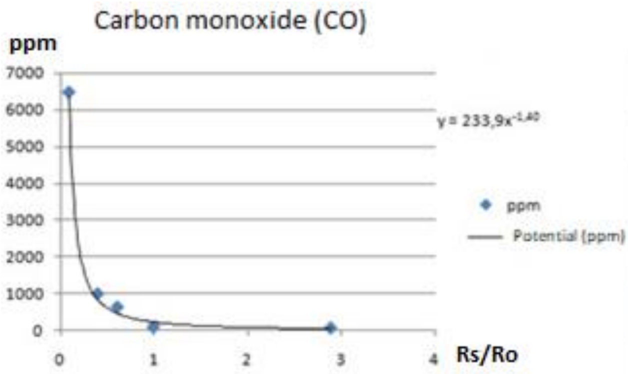


Fig. 2 Variables in MQ-135

This information shows the basic data for the measurement. To determine the air quality it is necessary to generate a regression equation and calculate the CO value. The trend line was graphed and the potential equation is chosen.



Curved points

Rs/Ro	ppm
0,096	6464,285
0,405	1000
0,614	640
1	100
2,894	73,214

Fig. 3 Sensor calibration curve

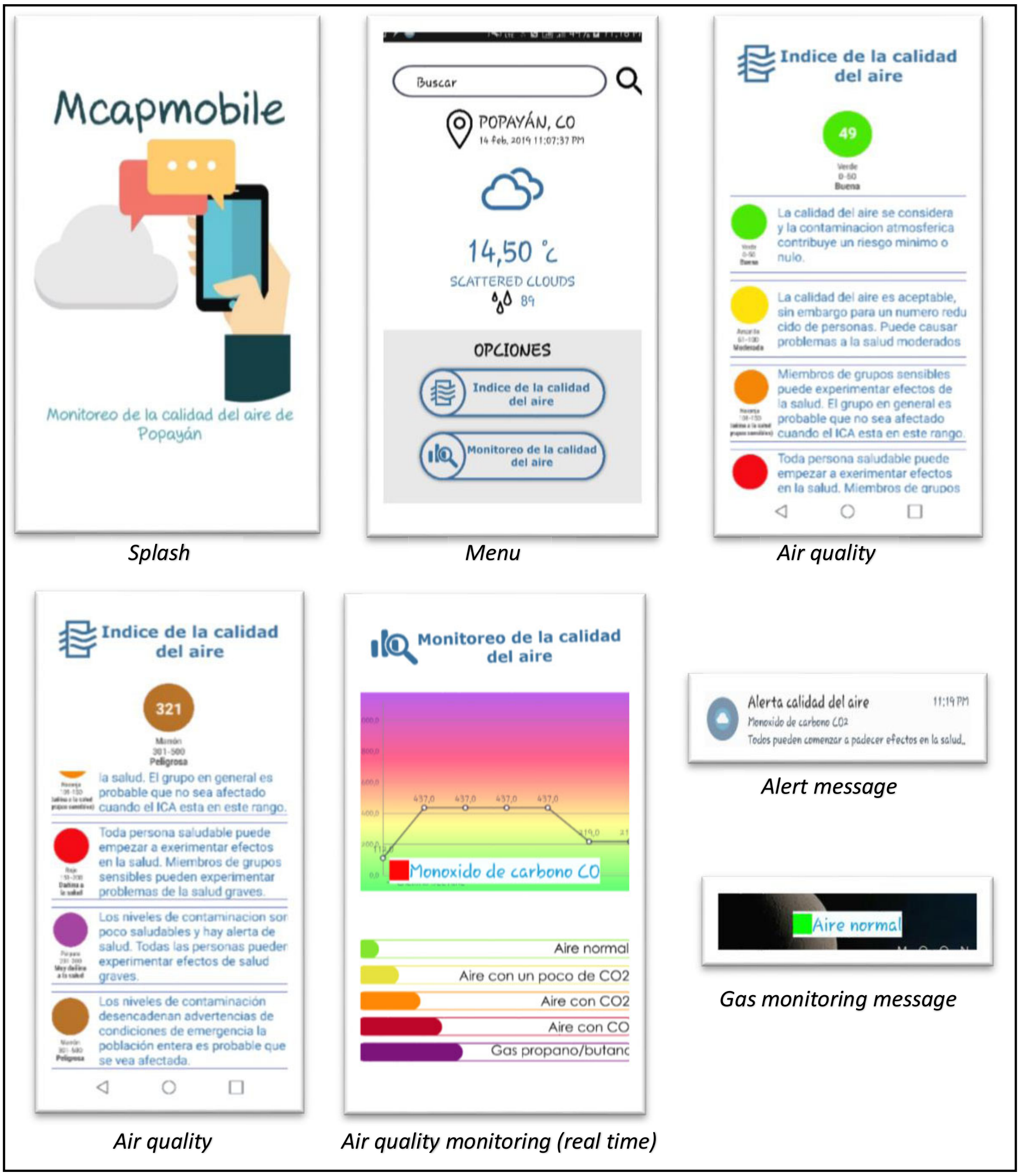


Fig. 4 Operation of the application

The modules of the Android application are described below:

1) Splash: Home screen with the MCAPMOBILE mobile application logo (figure 4).
2) Menu: Shows the options; the current location or search for a location, weather information, air quality index, and air quality monitoring.

a) Current location: location of the physical device is used.
b) Search for a place: Users can search for a place to know air quality in a certain place
c) Climate information: It gives information in real-time of the current temperature of the city and humidity.
d) Air Quality Index: an AQI (air quality index) is displayed with its respective ranges.
e) Monitoring of Air Quality: A graph displays real time alerts and recommendations on air quality.

T*est Phase:* The application was installed on the cell phones of some users to measure the user's experience. It was observed that the application was intuitive and easy to use, and users could observe the alerts generated by indicating their risks and the precautions they should take.

To calculate the Colombian Air Quality Index (AQI), a conversion of the data obtained from ppm to ug/m³ is required (micrograms over cubic meters) see EQ1:

$$\frac{Ug}{m3} = \left(\frac{PPM*PPM}{24.5}\right) * (10^3) \qquad (1)$$

where:

- $PPM = parts\ per\ million.$
- $PM = molecular\ weight(\ CO)$ [8].

The source code is:

- Double monoxidoMicroGramos = monoxidoDeCarbono $* \ 28.01 * \left(\frac{10^3}{24.5}\right);$

a) Data

Once the data is obtained, the Air Quality Index (AQI) is applied, which is determined by the following formula EQ2:

$$AQI_P = \frac{I_{HIGH}-I_{LOW}}{PC_{HIGH}-PC_{LOW}} * (\ C_P - PC_{LOW}) + \ I_{LOW} \qquad (2)$$

Where:

- AQI_P= Index of air pollution for the pollutant.
- C_P= Measured concentration for the pollutant.
- PC_{HIGH}=cut off point greater or equal to C_P.
- PC_{LOW}=cut off point less than or equal to C_P.
- I_{HIGH}= AQI corresponding to PC_{HIGH}.

IOP Conf. Series: Journal of Physics: Conf. Series **1247** (2019) 012054 doi:10.1088/1742-6596/1247/1/012054

- $I_{LOW} = AQI$ corresponding to PC_{LOW} [9].

Table 1 shows the cutoff points of the AQI for the pollutant:

Table 1 Air pollution index Colombian regulation

AIR QUALITY INDEX			AQI CUTTING POINTS
AQI	COLOR	CATEGORY	CO mg/m³, 8 HOURS
0-50	**Green**	Good	0-5094
51-100	**Yellow**	Acceptable	5095-10819
101-150	**Orange**	Harmful to sensitive groups	10820 -14254
151-200	**Red**	Harmful to sensitive groups	14255-17688
201-300	**Purple**	Very Harmful to health	17689-34862
301-500	**Brown**	Dangerous	34863-57703

Applying the formula as an example:

$$AQI = \left(\frac{100-51}{10819-5095}\right) * (6780{,}15 - 5095) + 51$$

$$AQI = 65{,}43$$

That indicates an acceptable air quality index according to the AQI table [10].

4. Results

The measurements were made in the parking lot and in a house every 30 minutes for 12 hours during a week. The devices were placed inside the parking lot and inside the home. In the early morning, a higher concentration of carbon monoxide (CO) is perceived. As hours passed, a slight decrease is observed, at noon and in the afternoon the levels of CO continue growing and decreasing slightly. The Air quality index (AQI) ranges between 50 (good air quality and no risk to health) and 100 (acceptable, although some respiratory symptoms can occur in sensitive population groups).

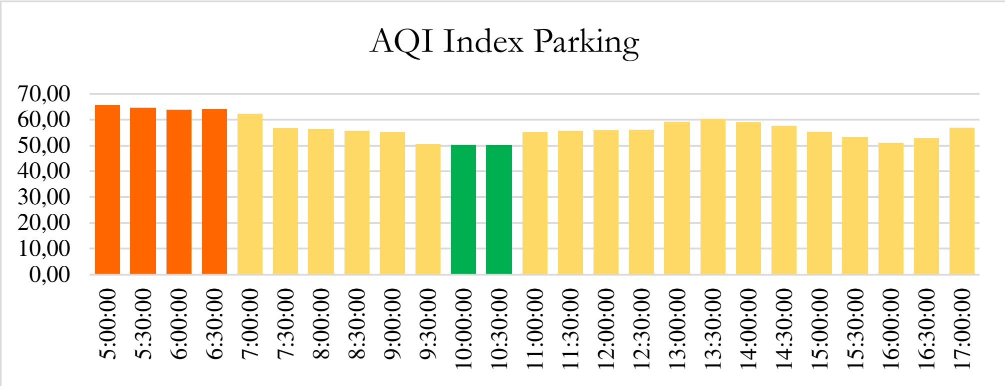


Fig. 5 Air quality index in the parking lot

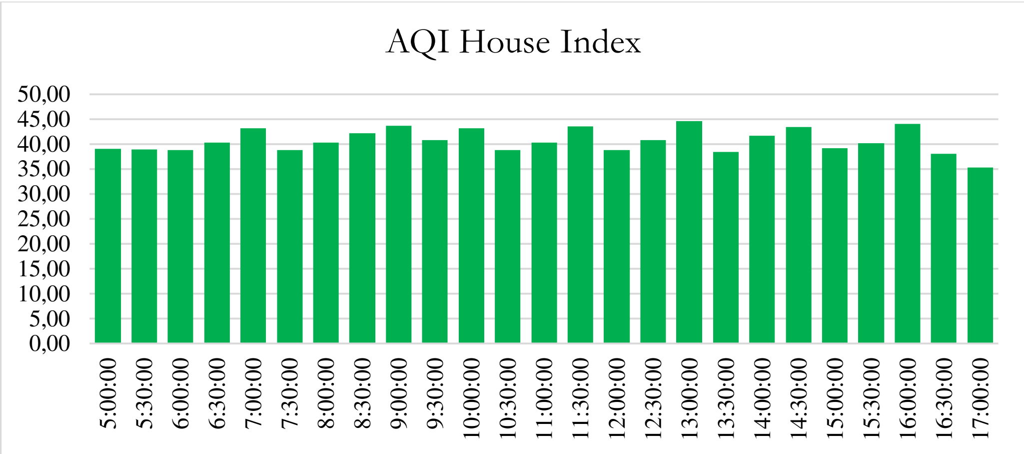


Fig. 6 Air quality index in the house

The device located in a house with moderate traffic congestion in the city of Popayan presents acceptable AQI that ranges between 35 and 44 (no risk). As expected, the air quality index in the parking lot exceeds the indexes obtained in the home. In the study, it was observed that the highest level of concentration is associated with high traffic of vehicles. By socializing in the application, users could see the risks to which they were exposed, so they decided to take action (for example the use of face masks)

5. Conclusions and future works

In order to mitigate the impact of air pollution in health, it is very important to know the indexes associated with the environment. This could improve the empowerment of the community regarding measures such as reduce the use of private vehicles or use facemasks. With the deployment of this prototype, it was possible to collect relevant information on air quality in the city of Popayán. This information was shared with the community in order to improve its empowerment.

Internet of things offers a feasible alternative for building this kind of architectures at a very low cost (38.40 USD). Future work includes the analysis of a large amount of data collected in order to forecast the air quality. Equally, new variables will be included in the platform.

IOP Conf. Series: Journal of Physics: Conf. Series **1247** (2019) 012054 doi:10.1088/1742-6596/1247/1/012054

6. Acknowledgements

The authors thank the Colombian Government, specifically the General Royalty System for financing this research through the Cauca Innovation Project (Doctoral Insertion Agreement).

7. References

[1] K. R. Smith *et al.*, "Public health benefits of strategies to reduce greenhouse-gas emissions: health implications of short-lived greenhouse pollutants.," *Lancet (London, England)*, vol. 374, no. 9707, pp. 2091–2103, Dec. 2009.

[2] A. M. Kirthima, "Air Quality Monitoring System using Raspberry Pi and Web Socket," vol. 169, no. 11, pp. 28–30, 2017.

[3] R. Baklouti, A. Ben Hamida, M. Mansouri, M. F. Harkat, M. Nounou, and H. Nounou, "Effective monitoring of an air quality network," *2018 4th Int. Conf. Adv. Technol. Signal Image Process. ATSIP 2018*, no. 4, pp. 1–4, 2018.

[4] A. Kumar, A. Kumar, and A. Singh, "Energy efficient and low cost air quality sensor for smart buildings," *3rd IEEE Int. Conf.*, pp. 17–20, 2017.

[5] D. Mendez, S. Diaz, and R. Kraemer, "Wireless technologies for pollution monitoring in large cities and rural areas," *24th Telecommun. Forum, TELFOR 2016*, 2017.

[6] A. M. F. León and R. T. Fernández, "DESIGN THINKING EDUCATIONAL INNOVATION AND METHODOLOGICAL RESEARCH," p. 6.

[7] R. Tem, "MQ-135 Datasheet," vol. 1, pp. 3–4.

[8] Ministerio de Ambiente Vivienda y Desarrollo Territorial, "Manual de Operación de Sistemas de Vigilancia de la Calidad del aire," p. 287, 2008.

[9] M. y E. A. Instituto de Hidrología, "Índice de calidad del aire (ICA). Formato Común Hoja Metodológica," *Ideam*, pp. 1–8, 2012.

[10] Ministerio de Ambiente y Desarrollo sostenible, "Resolución No. 2254." p. 11, 2017.

[11] Z. Aslam, W. Khalid, T. Ahmed, and D. Marghoob, "Automated control system for indoor air quality management," *ICECE 2017 - 2017 Int. Conf. Energy Conserv. Effic. Proc.*, vol. 2018–Janua, pp. 85–88, 2018.