Prototype of a Data Logger for Monitoring Carbon Dioxide and Particulate Matter Concentrations in Juliaca

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Abstract. The objective of this research was to develop a prototype low-cost portable data logger that monitors real-time air quality parameters such as carbon dioxide (CO_2) and particulate matter (PM_{10}) concentrations. The data logger prototype was built based on an Arduino Nano board as central processing. It also includes a sensor module that measures carbon dioxide (CO_2) concentration levels through the air quality sensor CCS811 and particulate matter concentration less than PM_{10} using the dust sensor GP2Y1014AU0F. Three different points in the city of Juliaca were selected according to the flow of pedestrian and vehicular traffic, such as called "Salida a Arequipa", "Salida a Lampa", and "Mercado Santa Barbara". The results obtained in the concentration of particulate matter less than PM_{10} in the three reference points are below the average allowed according to WHO (50 $\mu g/m^3$), and the results of carbon dioxide (CO_2) concentration levels are less the TWA 5000 ppm in the three monitored points according to NTP 549.

Keywords: Air quality · Particulate matter · Carbon dioxide · Data logger

1 Introduction

Industrialization and the development of society have brought benefits to people's material life, but at the same time, they have created several harmful effects on the environment. Likewise, smog, automobile exhaust fumes, industrial gas emissions, forest fires, among others [1] are factors that pollute the air. Among the various hazardous air pollutants are fine particles that negatively impact human health and are the leading causes of cardiovascular and respiratory diseases such as lung cancer and asthma [2–4].

Stationary, complex, and expensive equipment is usually used to monitor air pollution at a given location. Today this paradigm is changing due to the development of engineering. In the scientific literature, we find a variety of methods and designs to measure concentrations of particulate matter (PM), carbon dioxide (CO_2), and other compounds. In the scientific literature, we found papers describing constructions of air quality monitoring systems with low-cost components for the end user [5–10]; we

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also found air monitoring systems that use Wi-Fi communication to transfer their data [1, 11–13], even modernizing the available smartphones [3] and finally, we found air measurement applications for the Internet of Things [2, 14].

We should pay close attention to air quality, especially the concentration of delicate particulate matter below PM_{10} and CO_2 measurements. However, no study describes air quality monitoring for these two types of engagements together. Therefore, this work aims to develop a prototype of a portable data logger, which monitors air quality as well as PM_{10} and CO_2 concentrations at three different points in the city of Juliaca.

2 Monitoring Point

To monitor the air quality in the city of Juliaca, southern of Peru, three strategic observation points were established in three different characteristic places of greater mobility of vehicles, brick factories, and concurrence of people in the city of Juliaca, called as: "Salida a Arequipa" (Coord. E = 376850.23, N = 8286188.18), "Mercado Santa Barbara" (Coord. E = 378017.82, N = 828674.04), and "Salida a Lampa" (Coord. E = 377265.07, N = 8286994.08). Each of these monitoring points is strategical of the houses. The data captured at the monitoring points were 24 h continuous [15].

2.1 Monitoring Parameters and Legal Frame

The parameters to be monitored in the city of Juliaca were the concentration of particulate matter less than PM_{10} and the level of CO_2 concentration.

For the environmental air quality criteria, the following legal instruments were considered, such as World Health Organization (WHO-2021) Air Quality Guidelines (Table 1) and NTP549 international technical standards for carbon dioxide (Table 2).

Table 1. Air quality guidelines (WHO—Air) [4]

Pollutant	Averaging time	Value ($\mu g/m^3$)
PM_{10}	24 h	50
	Annual	20

Table 2. Air quality CO_2 (NTP549) [16]

Gas	Specific measures exhibition	Value (ppm)
CO_2	Outdoor air	300–400
	TWA LEP/8 h	5000
	STEL x 15 m	15000

Equation (1) represents the Time-Weighted Average (TWA) that will be used to calculate the average CO_2 allowable value.

$$TWA = \frac{\sum_{i=0}^{n} C_i \times T_i}{8} \quad (1)$$

where,
C_i = i-th concentration.
T_i = exposure time in hours associated with each value C_i.

3 Hardware Description

In this section, we present the design of a prototype air quality data logger. The data logger is portable, lightweight, easy to handle, and relatively small in size. The data readings are in real-time.

Figure 1 shows the design of the Data Logger, which consists of the following components: b) screen Thin Film Transistor-Liquid Crystal Display (TFT-LCD), c) LED indicator for data recording (".txt") in SD memory card, d) Arduino Nano board, e) Real-Time Clock (RTC) for date and time, f) RJ45 connection for protocol communication—I2C (Inter-Integrated Circuit), g) Dust sensor GP2Y1014 for detection of particulate matter (PM), h) Gas Sensor CCS811 for monitoring CO_2, and i) Power LED.

The Arduino C ++ IDE Platform was used for its programming. The data logger uses a 1.5 m UTP (Unshielded-Twisted-Pair) cable for communication between the sensor module and the central module of the data logger. The Data logger works with a power supply of 5VDC/500 mA at 100/240VAC—50/60 Hz.

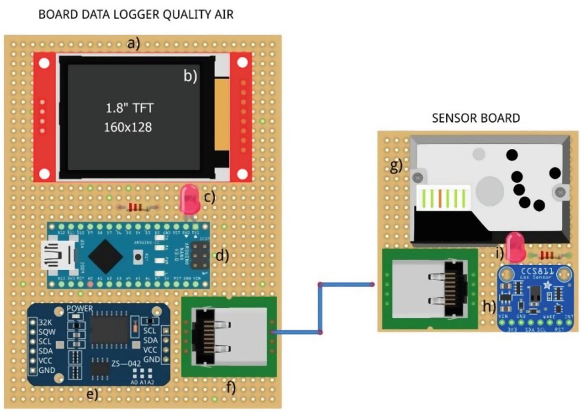

Fig. 1. Design of a prototype data logger of air quality.

Figure 2 shows data logger operation and computer algorithm expressed in a flow diagram.

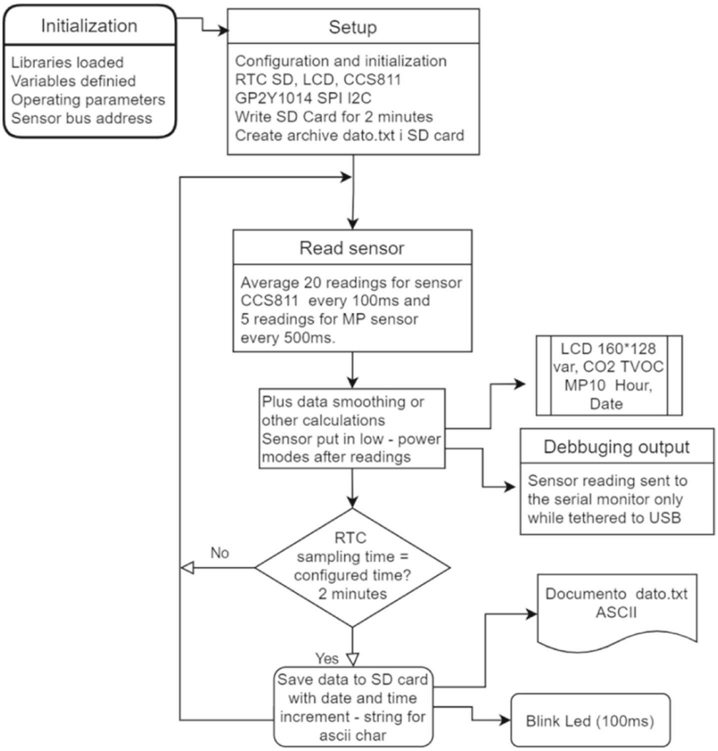

Fig. 2. Data logger operation flow diagram.

3.1 Selection Sensor

Dust Sensor GP2Y1014AU0F. It is an analog output model that detects particle concentration. In its interior, we find infrared light-emitting diodes and photodetector crystals placed diagonally for its operation, using the principle of light sensitivity. Its structure has a hole on each side for the passage of dust. When the air contains dust particles and enters the sensor chamber, the light from the LED emitter is scattered to the photodetector. The dust sensor emits a voltage value that varies according to the intensity of the scattered light, which corresponds to the level of dust in the air. Table 3 presents the parameters of the dust sensor GP2Y1014AU0F.

CCS811 Sensor. Low power digital gas sensor detects a wide range of total volatile organic compounds (TVOC), plus carbon dioxide equivalent (CO_2). The sensor provides readings of parts per million (ppm) of CO_2 and parts per billion (ppb) of TVOC. Table 4 shows the parameters of the CCS811.

Table 3. Parameters of GP2Y1014AU0F [17]

Specification	GP2Y1014AU0F
Ligh emitting element	LED
Minimum detectable dust size	0.5 μm
Dust density sensing range	Up to ~580 μg/m^3
Output interface	Analog
Output under zero dust conditions	0.1 to 1.1 V
Sensitivity	0.5 ± 0.075 v per 100 μg/m^3 change
Accuracy	Accuracy ±15%

Table 4. Parameters of CCS811 [18]

Specification	CCS811
Output:	vía I2C
Supply voltage:	1.8 V a 3.6 V
Power consumption:	1.2 mW a 46 mW
Detection of Total Volatile Organic Compounds (TVOC)	0 ppb to 1187 ppb
eCO2 detection	400 ppm up to 8192 ppm

4 Experimental Results

Figure 3 shows the average values of PM_{10} concentration levels during 24 h. We observed that the concentration of PM_{10} was higher at the "Salida a Lampa" with a total average of 33.9 μg/m^3 because it is a mixed asphalt and dirt road; PM_{10} concentration was lowest at "Mercado Santa Barbara" with 8.5 μg/m^3. We can observe that all the averages obtained are below the norm established by the WHO (50 μg/m^3); therefore, the three sampling points have lower concentrations of particulate matter less than PM_{10}.

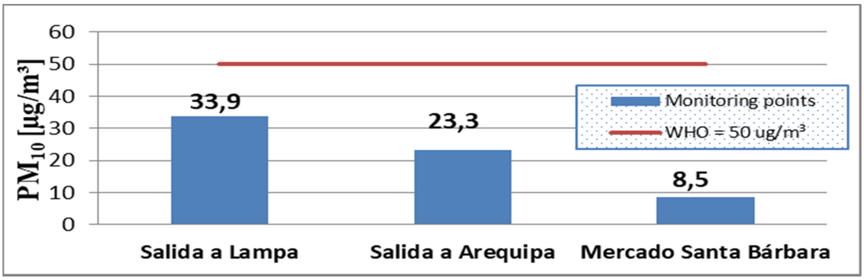

Fig. 3. Concentration of particulate matter lower than PM_{10} in three different points in Juliaca.

In Fig. 4, we observe the behavior of CO_2 in the "Salida a Lampa." The minimum value is 575 ppm, and the maximum is 5567 ppm. The representative TWA average is 2728.3 ppm. This average value is within the exposure limit value of 5000 ppm indicated in NTP 549. We find a greater flow of vehicular traffic in this area because it is a primary avenue and artisan brick factory.

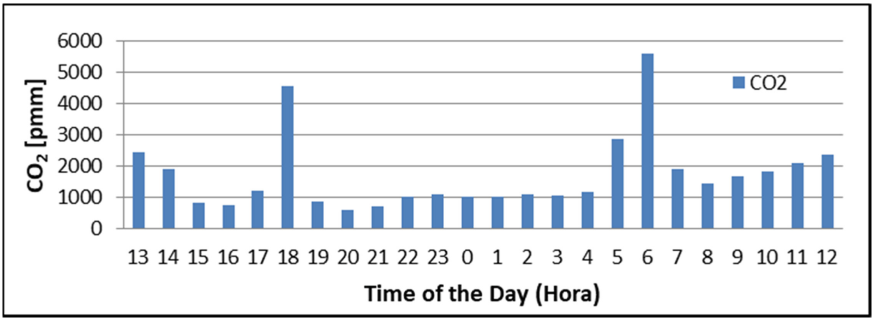

Fig. 4. Carbon dioxide concentration the "Salida a Lampa".

Figure 5 shows the behavior of CO_2 in the "Salida a Arequipa," the minimum value was 569 ppm, and the maximum value was 2625 ppm. The representative TWA average was 2028.3 ppm. Consequently, these values are within the exposure limit value of 5000 ppm indicated in NTP 549. In this area we find vehicular traffic flow, being a main avenue of the city.

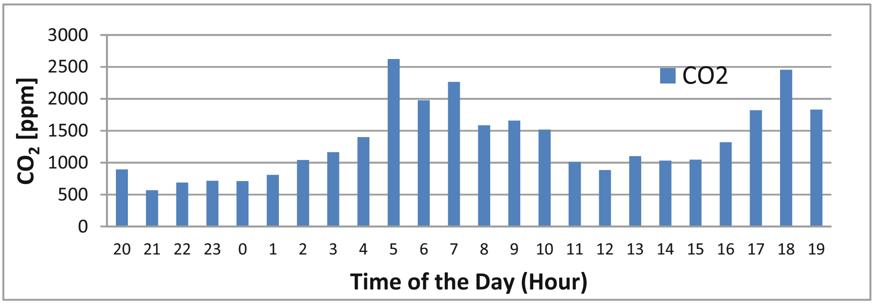

Fig. 5. Carbon dioxide concentration at "Salida a Arequipa".

In Fig. 6, we observed the behavior of CO_2 at "Mercado Santa Barbara". The minimum value was 499 ppm, and the maximum value was 2189 ppm. The representative TWA average was 1778.75 ppm. Consequently, these values are within the exposure limit value of 5000 ppm indicated in NTP 549. In this area, we find a more significant influx of pedestrians, many shopping centers, and public and private vehicles transit.

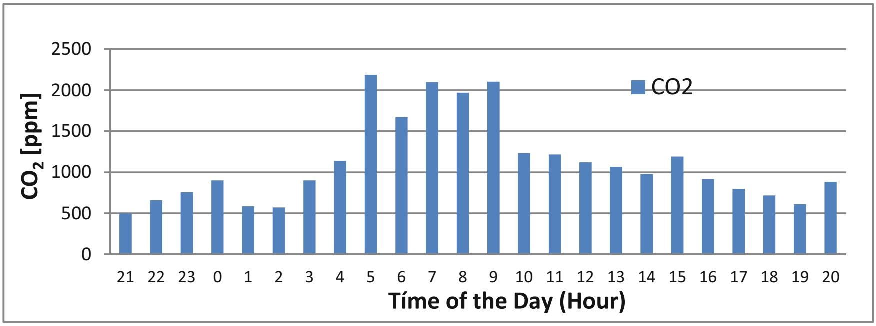

Fig. 6. Carbon dioxide concentration at "Mercado Santa Barbara".

5 Conclusion

In this work, a prototype of a portable data logger has been developed to continuously monitor air quality at three different points in the city of Juliaca. The data logger was built with low-cost components, available in the market, small size, and low power consumption. The data logger includes two sensors, first measure the concentration of particulate matter less than PM_{10} using a dust sensor GP2Y1014AU0F and the second measures carbon dioxide (CO_2) using the CCS811 sensor, whose values are displayed on the TFT-LCD screen, the data are stored directly in the data logger's SD Memory Card. The results from the dust concentration lower than PM_{10} was higher at the "Salida a Lampa" with 33.9 $\mu g/m^3$, however, it was lowest in the "Mercado Santa Barbara" with 8.5 $\mu g/m^3$. These results do not exceed the WHO guideline ($PM_{10} = 50\ \mu g/m^3$ over 24 h). The results of carbon dioxide CO_2 are within the permissible exposure limit according to NTP549. In future work, a network of sensors will be implemented for real-time monitoring at various points.

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