How to Cite:
Sivakumar, S., & Ramya, V. (2022). Design of IoT based mobile AQI monitoring kit: MyAmbiAQI kit. *International Journal of Health Sciences*, *6*(S4).
https://doi.org/10.53730/ijhs.v6nS4.10628

Design of IoT based mobile AQI monitoring kit: MyAmbiAQI kit

Sivakumar S*
Department of Computer Science and Engineering, FEAT, Annamalai University, Annamalainagar, Tamilnadu, India
*Corresponding author

Ramya V
Department of Computer Science and Engineering, FEAT, Annamalai University, Annamalainagar, Tamilnadu, India

***Abstract*---**Air quality is the consequence of interaction among several intricate factors involved in chemical reactions, and emissions from natural and anthropogenic sources. Pollution sources like industrial region, traffic zones, mines etc impose higher pollution levels. Appropriate measures and steps for reducing the pollution need to be taken for the well-being of people living nearer to these regions, with the fast pace of air pollution growth, the toxic levels in air need to get quantified accurately. The proposed MyAmbiAQI kit serves as an affordable and reliable solution for measuring the air quality index.it employs IoT modules and sensors in a centralised, portable and battery powered hub. The live responses from the sensors are acquired by the developed kit for precise monitoring of air quality. The data is sent to the cloud instantly using Thingspeak API and MQTT protocol. A visualization of data is made from the cloud dashboard there by having a constant check on the air quality around us. It is a monitoring device undesigned by WSN, and IoT based method design. Interior performance assessments and the comparison among these categories were performed with respect to their architecture and the incorporated tools. Additionally, the kit is compared with the existing AQI kits in terms of running life time, wake up time, response time and power consumption. The developed MyAmbiAQI kit has surpassed the limitations in existing kits and provides more reliable data.

***Keywords*---**air quality index (AQI), AQI monitoring kit, AQI parameters, raspberry Pi, AQI kit performance.

Manuscript submitted: 27 April 2022, Manuscript revised: 18 June 2022, Accepted for publication: 9 July 2022

Introduction

The airborne diseases and its influence in fatality rates is expanding hugely over these years that resulted in several complications such as asthma, toxicity in blood, rashes in skin, acute bronchitis, diseases in coronary artery and pulmonary infections [1]. Every year, two major sources namely: automobiles and industries discharge a large amount of air pollutants such as smog, smoke, toxic gases into the environment that degrades the quality of air. The extravagance in usage of vehicles in urban areas has also added to the increased emission of toxic gases like airborne Particulate Matter in the environment. It leads to several human health and biological related problems including irregular patterns in rainfall, acid rain, global warming and other climatic changes [2]. Airborne particulate matter (PM) is extensively recognized as an air quality problem. Pollutants like smog, Carbon monoxide, Ammonia, Methane, nitrogen dioxide, Sulphur dioxide and other greenhouse gases are smaller in size and invisible, due to which, these are neglected by people. Such kinds of negligence induce severity over humans, animals, water and climate. Therefore, the demand for environmental pollution monitoring system is a growing need safeguard people from these malicious effects. Due to this, several nations are adopting standards for the Air Quality Index.

The AQI measures the purity of air and emphasize over the influence of polluted air inhalation in human beings within a few hours or days of inhalation [4]. The Environmental Protection Agency (EPA) computes the index value for air quality in PPM (Part per Million). It has formulated certain standards for five major air pollutants to protect public health and to maintain the air quality as given Table 1.1. Five classes of pollutants are: ground-level ozone, particulate matter (PM), carbon monoxide (CO), sulphur dioxide (SO2) and nitrogen dioxide (NO2). The proposed device monitors and provides solution for detection of AQI value that is air pollution and the deteriorated air quality through a smart mobile/PC. It monitors the AQI from time to time and intimates if the value of AQI exceeds the threshold value. The device interfaces among environment, public and government and is flexible as it can be installed at any place and operated effortlessly.

Table1.1 Standard representation of AQI levels defined for health concerns

Air Quality Index Levels of Health Concern	Numerical Value	Associated Health Impact
Satisfactory	51 to 100	May cause minor breathing discomfort to sensitive people
Moderate	101 to 200	May cause breathing discomfort to the people with lung disease such as asthma and discomfort to people with heart disease, children and older adults
Poor	201 to 300	May cause breathing discomfort to people on prolonged exposure and discomfort to people with heart disease
Very Poor	301 to 400	May cause respiratory illness to the people on prolonged exposure. Effect may be more pronounced in people with

		lung and heart diseases

Literature Survey

Automobiles and industries are the two major sources of air pollution in urban areas. The smog is formed because of the discharged smoke getting mixed with fog/dust in winter season. It leads to poor visibility and foggy sky [5,9]. Semi-conductor-based sensors are been used in present day vehicles. These sensors are attached to the smoke emission outlets of vehicles. The sensor senses the levels of pollutant and alerts with a alarm sound to denote that the emitted pollutants have exceeded the threshold level and stops the after some time. This methodology is comparatively good only for individual users and not for the public. [6].

An IOT based Air and Sound Pollution Monitoring System is presented by Arushi Singh et al. using Raspberry Pie & Arduino. The proposed device can be kept at schools, clinics and no honking area areas that detects the quality of air, noise and reports alerts using Raspberry Pie Server. [2]. Raspberry Pie is not easily affordable and bulky in size are the major drawbacks. The Thingspeak (IoT platform) over a TCP Connection is developed by Yamunathangam et al. using Arduino & Ethernet shield unified with gas sensors to detect the concentration of gases such as carbon monoxide(CO), ammonia, particulate matter(PM), humidity and smoke[3]. Arduino and Ethernet 's size is the major concern to be noted.

MQ series sensor measure the gases like CO, CO_2, SO_2 and NO_X using semiconductor sensors. Gagan Parmar et al. developed a hardware using Rasp berry Pie and STM32/8 Arm Controller for monitoring the system. [4]. The web server is created by Raspberry Pie where data can be monitored and regulated. Node MCU ESP8266, a modern chip based on wifi is used by Vijayakumar Sajjan et al. The MQ Series sensor collects air quality data and uploads the data to Thingspeak Server [5]. The developed system is cost effective and uses a very small quantity of power. The machine learning algorithm is employed in predicting the future values of gases.

An Air Quality Monitoring System combining Arduino, air quality sensor, temperature & humidity sensor using Wi-Fi modules is developed. Modbus relays the communication of data. Vb.net application is utilized for the ports of PC in observing the data [6]. GSM modules are used for further transferring of data. To measure Airborne Particle Concentrations, a system is developed by David Brooks using Arduino. Laser scattering method is adopted for measuring the size or diameter of particles. In this method, laser beam is shined across a chamber through which flow of air is conducted. Varying sized airborne particles are strike by air beam. During striking, beam's portion is diverted which gives, amount proportional to the size and density of the particles [9] but this is more complex in nature.

An IoT Based Air Pollution Monitoring is proposed using sensor-based hardware module to place along roadways and the information can be utilized in traffic control. The modules are affixed in lamp posts which transmits the air quality information to server wirelessly [8]

Proposed System

Sensing of air quality pollutants using multi-sensory kit is developed for AQI data logging on daily basis. The overall work is depicted in the block diagram Figure 3.1. The proposed model is constituted by three main functional blocks such as hardware setup, data collection and cloud storage. The developed model is then evaluated in two ways: with hardware performance and data performance. This functional block is detailed in the below sections.

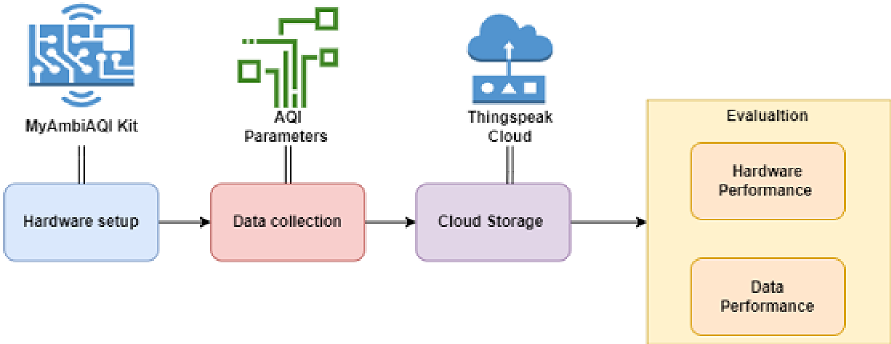


Figure. 3.1 Overall block diagram of MyAmbiAQI model representation

Hardware setup

The MyAmbiQI kit hardware setup and schematic model is depicted in Figure 3.2 and real-time proposed model is shown in Figure 3.3. The configuration of each sensor and their features are been described in Table 3.1.

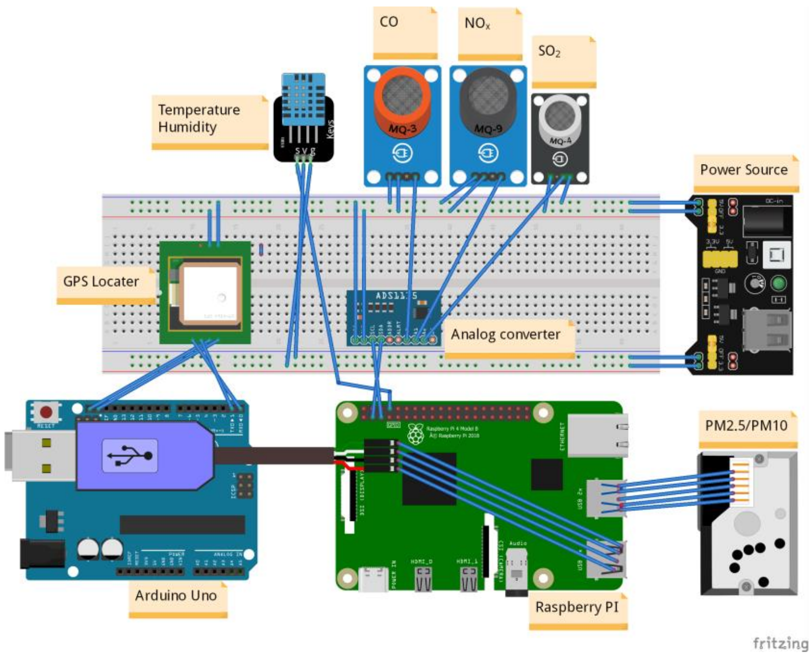


Figure.3.2 The schematic representation of MyAmbiAQI kit

In this model, Arduino Uno is incorporated for collecting the live location parameter using GPS locater module and serially connected to raspberry Pi to send the captured location. The AQI parameter detecting sensors are connected to raspberry Pi through analog to digital convertor(ADC). The PM module is attached in serial port of raspberry Pi. The Pi using the external power source of battery acts as central controller of the proposed system. This proposed model uses WIFI communication and MQTT (MQTT) protocol to send and receive the data to cloud. This protocol uses MQTT broker for publishing and subscribing of AQI data on live basis, where each generated value is published to the subscribed cloud control.

Table 3.1. List of sensors and module deployed in MyAmbiAQI kit

Sensors & Hardware Modules	Features
Raspberry Pi 4 model	Controller of the proposed model to handle the real-time data and cloud
Arduino Uno	Module used for controlling the GPS locater
Laser PM2.5 Sensor--SDS011	To generate the PM10 & PM2.5 values
DHT 11	To check the temperature value
MG811 Module, Air Carbon Dioxide/CO_2 Sensor	To generate the CO value
Sulfur Dioxide SO_2 Analog Gas Sensor	To generate SO_2 value
Nitrogen Oxide NO_X Analog Gas Sensor	To generate NO_X value
UBlox NEO-M8M GPS Module with Ceramic Active Antenna	To store the live location data
ADS1115 16-Bit ADC- 4 Channel with Programmable Gain Amplifier	To convert the above AQI values from analog to digital value

Data Collection

The data generated from MyAmbiAQI kit is stored in the difference of 8 hours' time interval that is averaged for 24 hours data. The data collected are PM2.5(µg/m3), PM10(µg/m3), SO2(µg/m3), NOx(µg/m3) and CO(mg/m3) which altogether used for calculating AQI(ppm).Each sensor value is calibrated and filtered to stabilize error values and then stored in Thingspeak cloud. The data stored in the cloud can be visualized on live basis and also for downloading in .csv format. The collected data on daily basis logged for 11 days are shown in the Table 3.2.

Table 3.2. Sample AQI data generated from MyAmbiAQI kit

Date	PM2.5 (µg/m^3)	PM10 (µg/m^3)	SO2 (µg/m^3)	NOx (µg/m^3)	CO (mg/m^3)	AQI (ppm)
10-02-2021	57.92	94.82	14.35	15.98	1.06	97
11-02-2021	50.59	92.57	10.9	15.35	1	93
12-02-2021	42.88	68.01	16.63	15	0.75	71
13-02-2021	41.03	69.18	11.25	14.35	0.77	69
14-02-2021	39.79	62.87	8.34	12.56	0.78	66

15-02-2021	39.47	77.47	8.96	14.38	0.87	77
16-02-2021	42.9	77.12	8.66	13.99	0.86	77
17-02-2021	49.5	91.12	8.4	13.59	0.88	91
18-02-2021	52.44	75.55	8.57	13.02	0.83	87
19-02-2021	49.92	90.08	7.36	15.58	0.87	90
20-02-2021	21.93	37.85	5.86	18.61	0.85	43

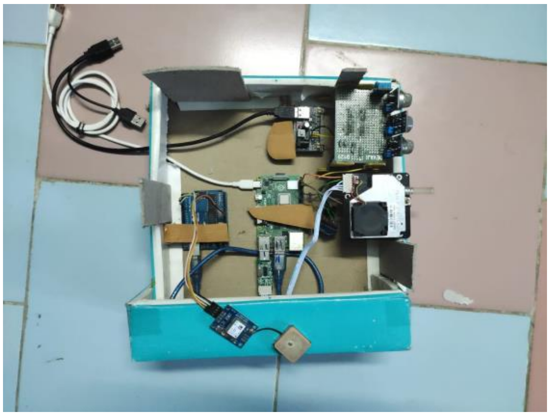
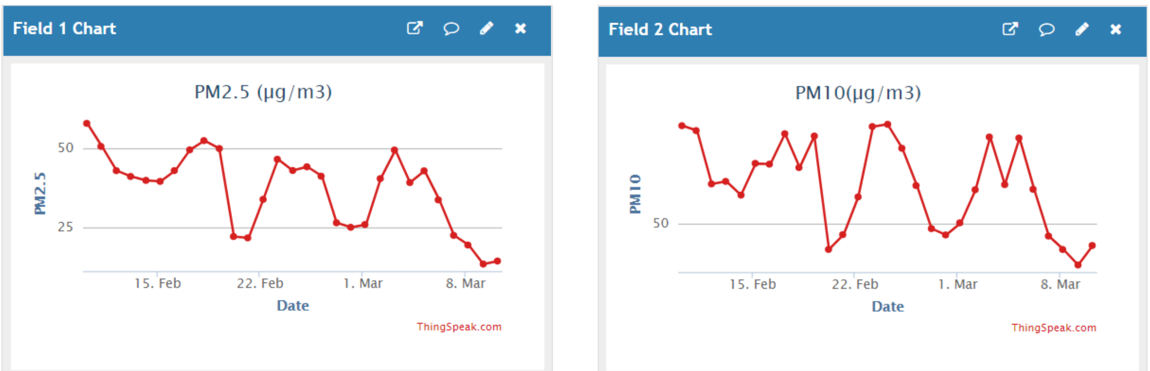


Figure 3.3 Realtime implementation of the MyAmbiAQI kit

Cloud Storage

In this model, Thingspeak cloud is incorporated with the proposed model for storage of the data for 8 hours of interval. Thingspeak cloud is majorly used in IoT live data storage in different IoT fields. In this work,cloud uses MQTT protocol to collect the data from the proposed kit using Thingspeak API. The MQTT broker of the cloud is subscribed to kit and the control is shown in the dashboard of Thingspeak. The AQI parameter stored in the cloud is represented in graphs as shown in Figure 3.4.



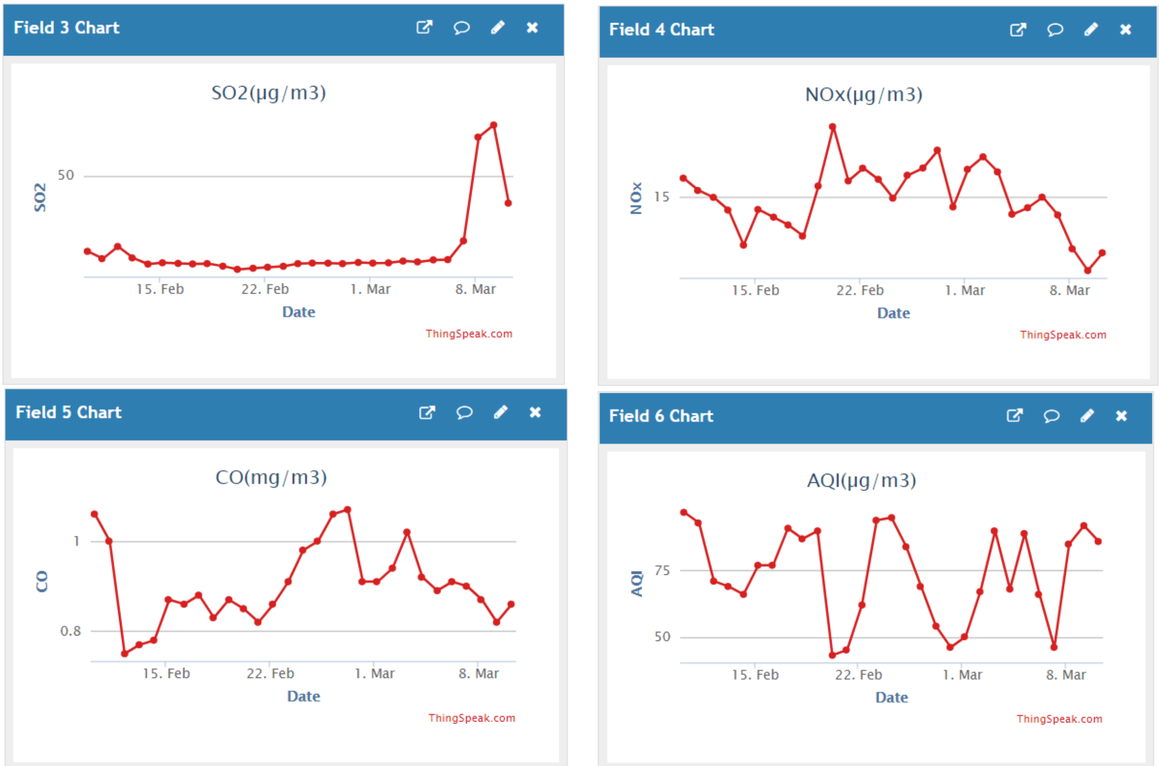


Figure 3.4 Representation of AQI data stored in the ThingSpeak

Evaluation & Analysis

In this work, the proposed model is evaluated in two ways that is data performance and hardware performance as shown in the block diagram Figure 3.1. From this evaluation the developed model can be checked for the performance by means of data generated and hardware working.

Data Performance

Data performance deals with the parameter generated from the kit is under the range of AQI levels as shown in the Table 1.1. The obtained value from each AQI parameter is measured and compared against the range fixed by the AQI levels. This value fulfils the range by proving the kit as a standard maintaining device. The AQI values are generated to the nearest of AQI parameter by classifying the AQI quality level as shown in Table 1.1. These values are compared against the ranges of the standard AQI levels represented in the Table 4.1 and Figure 4.1. From the figure, it can be inferred that the values generated are present in between the ranges of the AQI levels which makes the data reliable and acceptable. These levels can be further classified according to the quality levels and can show the live status in the cloud dashboard.

Table 4.1 The obtained value from the MyAmbiAQI kit

AQI Category	Standard value $PM_{2.5}$ 24-hr (µg/m³)	Obtained Value	Standard value PM_{10} 24-hr (µg/m³)	Obtained Value	Standard value SO_2 24-hr (µg/m³)	Obtained Value	Standard Value NOx 24-hr (µg/m³)	Obtained Value	Standard Value CO 8-hr (mg/m³)	Obtained Value	Standard Value AQI 24-hr (ppm)	Obtained Value
Good	0-30		0-50		0-40		0-40	11-18	0-1.0		0-50	
Satisfactory	31-60	13-58	51-100	30-95	41-80	5-73	41-80		1.1-2.0	0.75-1.07	51-100	43-97
Moderate	61-90		101-250		81-380		81-180		2.1-10		101-200	
Poor	91-120		251-350		381-800		181-280		10-17		201-300	
Very poor	121-250		351-430		801-1600		281-400		17-34		301-400	
Severe	250+		430+		1600+		400+		34+		401-500	

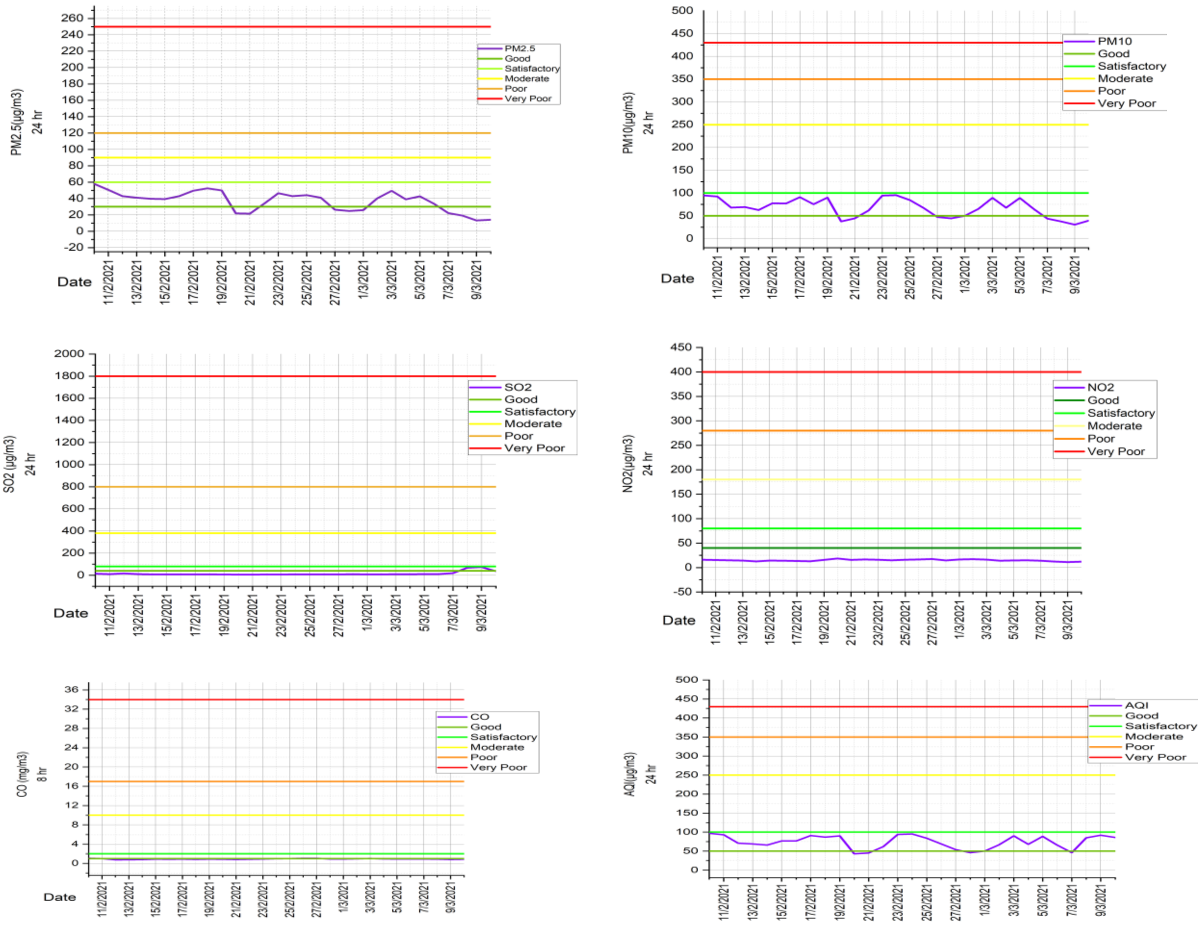


Figure 4.1 The graphs generated for the obtained value comparing against AQI ranges

Hardware Performance

The MyAmbiAQI kit is developed using low-cost sensors and module which is integrated altogether to form a multi-sensory Kit to generate the AQI datasets. In this work, the sensors and the modules are cost effective when compared with other AQI detection kits. Performance metrices of the proposed model is compared with other existing AQI hardware kits in terms of total runtime, wakeup time, response time and power consumption.

Performance Evaluation

The performance of the proposed system is compared against the existing hardware kit such as Aeroqual Handheld AQI monitor and Libelium Air quality IoT Kit. Total runtime is the metric used to calculate the total runtime of the system from the initialization to shutdown working., Wake up time is the total time taken to refresh and generate new datasets eventually. Response time is calculated for total time taken to collect, process, execute and uploading data to the cloud. Power consumption is the total power used for the executing of the proposed system. This performance metrices comparison is depicted in the Table 4.2.

Table 4.2 Performance metrices of the different AQI Kits comparisons

Performance Parameter	Aeroqual Handheld AQI monitor	Libellium Air Quality IoT Kit	MyAmbiAQI kit
Total Run time (Hours)	33	30	45
Wake up time (sec)	30	45	25
Response time (sec)	5 - 40	8 - 45	4 - 35
Power Consumption (W)	5.8	6.1	4.5

The multisensory MyAmbiAQI kit provides better results in performance analysis. It has active time higher than Aeroqual Kit and Libelium kit with 32.76% and 40% respectively. It provides reduced response time than the above cited kits with 22.2% and 66.66% accordingly. Wakeup time is also reported as 18.18% earlier with the Aeroqual kit and 40 % earlier to the Libelium kit. Finally in terms of power consumption 25.54% of the proposed kit power is reduced in comparison with Aeroqual kit and 30.18 % power is reduced in comparisons with Libelium kit.

Conclusion

In response to static, high-cost conventional air pollution monitors failing to capture the reliability of air pollution, need for affordable and reliable monitors is expanding. The degree of preciseness and consistency in existing AQI kits is unsatisfactory. MyAmbiAQI kit resolves this issue by adopting affordable sensors and cloud configurations in collecting the AQI data. The kit is fabricated to make the data more reliable and accurate compared to the real-time value generated by the nearest AQI station. In the proposed system the data and the hardware performance are evaluated. In the terms of data, the system provides the values in the range of the AQI quality standard and with respect to hardware, it performs better than the existing kits considered in this work.

References

1. Arushi Singh, Divya Pathak, Prachi Pandit, Shruti Patil, Priti C. Golar, IOT based air and sound pollution monitoring system, Int. J. Adv. Res. Electr. Electron. Instrum. Eng. 6 (3) (2017).
2. Bascom R, Bromberg PA, Costa, DA, Devlin R,Dockery DW, Frampton MW, et al. Health effects of outdoor air pollution. Am J Respir Crit Care Med 1996; 153:3 - 50 (Part 1); 477 – 498.
3. Chen T-M, Gokhale J, Shofer S, Kuschner WG. Outdoor air pollution: nitrogen dioxide, sulfur dioxide, and carbon monoxide health effects. Am J Med Sci. 2007.Apr; 333(4):249– 56.
4. D. Verma, S. Dhul, R. Saini, R.B. Dubey, IoT based air pollution monitoring system, Int. J. Innov. Res. Eng. Manage. (IJIREM) 5 (3) (2018), ISSN: 2350-0557.
5. David Brooks, An Arduino-Based System for Measuring Airborne Particle Concentrations, Institute for Earth Science Research and Education, https:// www.instesre.org/PM/PMMeasurements.htm.
6. Harsh N. Shah, Zishan Khan, Abbas Ali Merchant, Moin Moghal, Aamir Shaikh, Priti Rane, IOT based air pollution monitoring system, Int. J. Sci. Eng. Res. 9 (2) (2018), ISSN 2229-5518.
7. Hesterberg TW, Bunn WB, McClellan RO, Hamade AK, Long CM, Valberg PA.Critical review of the human data on short-term nitrogen dioxide (NO2) exposures:evidence for NO2 no-effect levels. Crit Rev Toxicol. 2009; 39(9):743–81.
8. K. Yamunathangam, P Varuna Pritheka, IOT enabled air pollution monitoring and awareness creation system, Int. J. Recent Technol. Eng. (IJRTE) 7 (4S) (2018).
9. Linn W S , S h a m o o DA, Anderson K R , Peng RC, Avol EL, Hackney JD, G o n g H Jr. Short-term air pollution exposures and responses in Los Angeles area schoolchildren. J Exposure Anal Environ Epidemiol 1996; 6: 449- 172.
10. Overview of Particle Air Pollution (PM2.5 and PM10), Air Quality Communication Workshop San Salvador, El Salvador April 16–17, 2012, https://www. epa.gov/sites/production/files/2014-05/documents/huff-particle.pdf.
11. Rusmini, R., & Hastuti, P. (2021). Local awareness based midwifery care in basic level service in the digital era . *International Journal of Health & Medical Sciences*, *4*(1), 69-73. https://doi.org/10.31295/ijhms.v4n1.1150
12. S. Muthukumar, W. Sherine Mary, et al., IoT based air pollution monitoring and control system, in: Proceedings of the International Conference on Inventive Research in Computing Applications (ICIRCA 2018) IEEE Xplore Compliant Part Number: CFP18N67-ART, ISBN: 978-1-5386-2456-2.
13. Samir Lemes, Air quality index (AQI) – comparative study and assessment of an appropriate model for B&H, in: Conference: 12th Scientific/Research Symposium with International Participation “Metallic and Non-metallic Materials” MNM 2018, Vlašic´, Bosnia and Herzegovina, 2018.

14. Schwartz J, Zeger S. Passive smoking, air pollution, and acute respiratory symptoms in a dairy study of student nurses. Am Rev Respir Dis 1990; 141: 62-67.
15. U.S. Environmental Protection Agency. Air quality criteria for carbon monoxide. Washington, DC,USA: Office of Research and Development,EPA-600/B-90/045F, 1991.
16. Vijayakumar Sajjan, Pramod Sharma, Research on an Iot based air pollution monitoring system, Int. J. Innov. Technol. Explor. Eng. (IJITEE) 8 (9S2) (2019), ISSN: 2278-3075.
17. Widana, I.K., Sumetri, N.W., Sutapa, I.K., Suryasa, W. (2021). Anthropometric measures for better cardiovascular and musculoskeletal health. *Computer Applications in Engineering Education*, *29*(3), 550–561. https://doi.org/10.1002/cae.22202
18. World Health Organization. Air Quality Guide-lines for Europe. Copenhagen, Denmark: WHO,Regional Office for Europe (in press).