Experimental Study on Automated Indoor Air Quality Monitoring

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Abstract— Many pollutants that come from various appliances and building materials that remain within a building, existing for long period without being controlled become hazardous to the health of humans and the buildings. Residential buildings are prone to various pollutants continuously and are often disregarded in terms of monitoring and control. This paper studies the concentration of CO_2, CO and dust particles and monitors them using MQ-135 gas sensor, MQ-7 gas sensor and GP2Y1010AU0F dust sensor. These sensors are interfaced with Node Microcontroller Unit (MCU) which sends the values of concentration that are monitored to the ThingSpeak (an IoT analytics platform), there the data get visualized, analyzed and stored. Then, the concentration data sent to the mobile phones of the occupants and displayed through the android application (which we developed using MIT App Inventor). Then, the system is evaluated by conducting test in indoor residential environment and the test results were compared with the limits set by World Health Organization (WHO) standards.

Keywords : Pollutants, Sensors, Node MicroController Unit, Monitoring, Mobile application

I INTRODUCTION

With rapid increase in urbanization, there is excessive air pollution within and around the living environment, causes direct and indirect impact on human lives. It has been estimated that, people spend about 90% of their time in both public and private indoor environments, such as homes, schools, work places, transportation vehicles, gyms, etc.; thus, IAQ has notable impact on health and quality of life in general [1]. Therefore, little attention and importance has been placed on air pollution within both public and private environments.

However, there are many conventional methods to monitor the indoor pollutant concentration, they were expensive and normally used by the professionals for walk-through or spot test only when a problem has been reported [2]. This led to research of an alternative methods, which is cost effective, widely-accessible. The IoT based air pollution monitoring, is an alternative for conventional methods. Internet of things (IoT) methodology communicates both devices and the humans electronically with respect to control module [3]. Life style controllability based on (IOT) became considerably simpler and easier especially in the communicating approaches among the smart devices [9]. A proper sensing and monitoring system are essential for the accomplishment of an efficient IoT system [10]. In this paper, we presented an efficient, low-cost automated IAQ monitoring system.

Automated IAQ monitoring is an application of IoT technology, where we can monitor the indoor pollutants concentrations without any manual intervention and it has the ability to transfer the monitored data over a network without requiring human-to-human or human-to-computer interaction. The air quality monitoring kit was developed with a wi-fi module, through which the monitored data were posted to the ThingSpeak (an open IoT platform). The wi-fi module used here is the NodeMCU. The ThingSpeak stores all the data posted, in the cloud, so that, for both online and offline analysis, the data can be accessed. ThingSpeak platform send the data to the connected mobile phones through web applications. Then, the data can be viewed from anywhere anytime through the connected mobile device. Fig 1.0 showing architecture of the proposed system. The system helps occupants to avoid the prolonged exposure to high concentration of pollutants. Thus, in this research, a real-time IAQ monitoring system is proposed and implemented in the real indoor environment. The system that we have developed is capable of monitoring three air quality parameters such as CO, CO_2, and PM simultaneously with a single module.

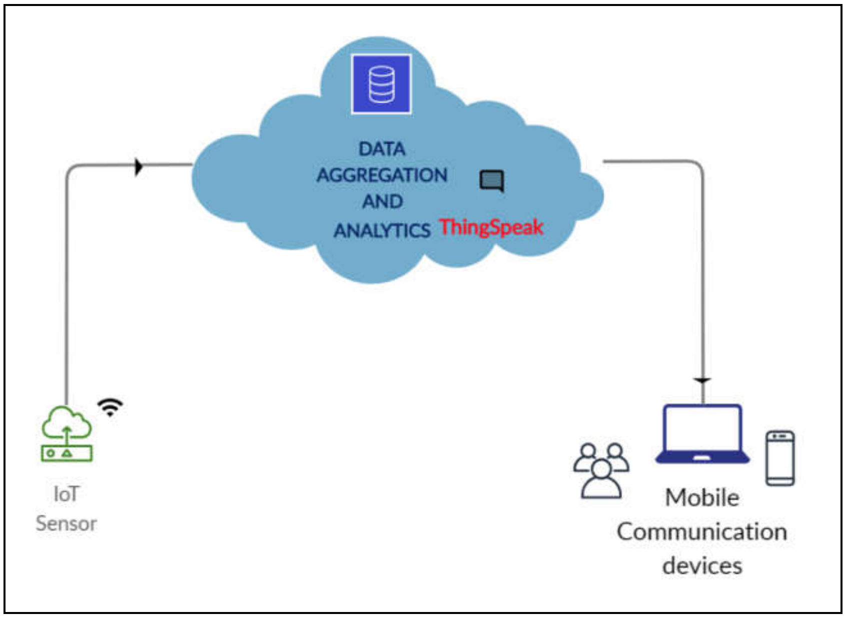

Fig 1.0 The architecture of the proposed system

II SYSTEM REQUIREMENTS

LIST OF HARDWARES USED

MQ-135 gas sensor

The MQ-135 [4] is a semiconductor gas sensor which detects the presence of Carbon dioxide at concentrations from 10 to 10,000 ppm. It consumes less than 150 mA. It is interfaced with Node MicroController Unit (MCU).

MQ-7 gas sensor

The MQ-135 [5] is a semiconductor gas sensor which detects the presence of Carbon Mioxide at concentrations from 10 to 10,000 ppm. It consumes less than 150 mA. It is interfaced with Node MicroController Unit (MCU).

GP2Y1010AU0F dust sensor

The GP2Y1010AU0F [6] compact dust sensor is designed to detect fine particles like cigarette smoke and dust. It measures particulate matter from 2.5 to 10 micron. This is interfaced with the Node MicroController Unit (MCU).

Node MicroController Unit (MCU)

The Node Microcontroller Unit (MCU) [7] is an integrated circuit chip which is an open source software and hardware development environment. It is used to transfer monitored data to an open source IoT platform.

ONLINE PLATFORMS USED

ThingSpeak platform

ThingSpeak is an IoT analytics platform service that allows the users to aggregate, visualize, and analyze live data streams in the cloud. It allows to access the data with or without internet connections, since it stores the complete data. In this platform, the data get charted as graphs or tables.

MIT App Inventor

The MIT App Inventor is a web application IDE (Integrated Development Environment) allows users to create android application. This platform helps to create android apps without any knowledge of programming, and just by dragging and dropping components into a design view.

III EXPERIMENTAL PROGRAMME

The kit as shown in Fig 2.0, developed by interfacing MQ135, MQ7 and GP2Y1010AU0F with Node MCU through Arduino programming. A ThingSpeak account is created and new channels are opened for each sensor data. The NodeMCU is programmed to read and store the sensor data and then upload it to ThingSpeak using the created channel name and API (Application Programming Interface) key. The NodeMCU should be connected to the internet through Wi-Fi. Then, an android application is created using MIT App Inventor (an online website to create applications), to view the air quality data from anywhere through mobile. After designing the system, the kit is calibrated and the residential indoor test environment is chosen as specified in Fig 3.0. The test was conducted for a period of 15 days and the performance of the system was evaluated. The air quality data was noted for the entire test period and compared with the WHO standards.

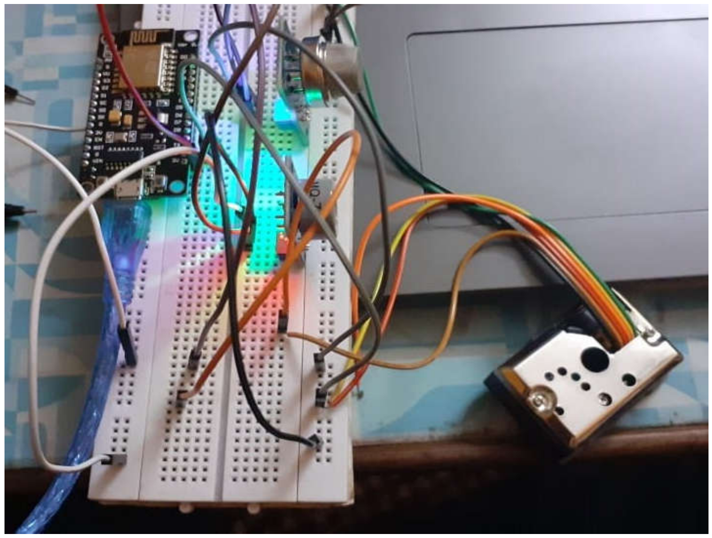

Fig 2.0 Air Quality test setup

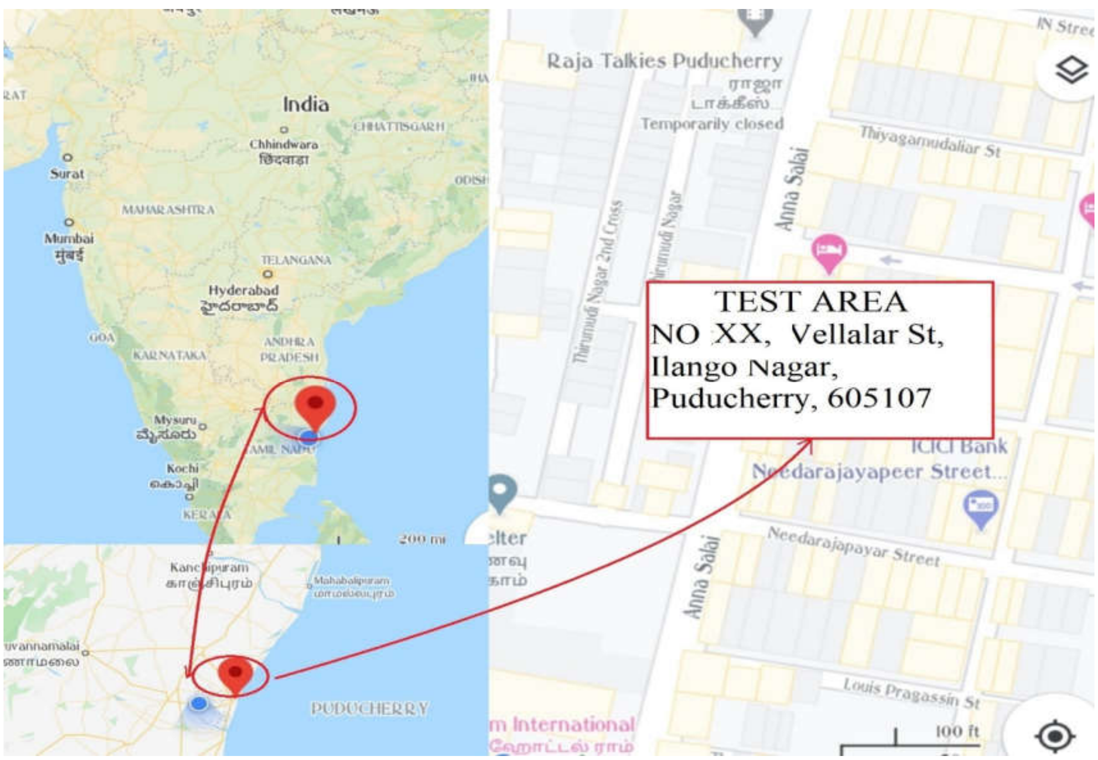

Fig 3.0 The location of the test area

IV RESULTS AND DISCUSSION

A residential indoor environment is chosen for testing and the kit was placed at the center of the area during the test period. For a period of 15 days, as per the WHO [8] recommendations, the test was carried for 8 hours per day. We have done the test from 9AM to 4PM. For every 1 hour, the results get displayed in the app as shown in Fig 7.0. Then, the results are tabulated, as shown from Table 1.0 to Table 3.0 and respective graphs are plotted, as shown from Fig 4.0 to Fig 6.0.

Carbon monoxide concentration

From the Table 1.0, it is observed that the carbon monoxide concentration ranges from 2.58ppm to 3.06ppm for an average period of 8 hours and it lies within the threshold value of 9ppm as set by the WHO recommendations.

Table 1.0 CO (Carbon Monoxide) concentration

Day	TIME (HOURS)								Average of 8 hours
	8AM TO 9AM	9AM TO 10AM	10AM TO 11AM	11AM TO 12PM	12PM TO 1PM	1PM TO 2PM	2PM TO 3PM	3PM TO 4PM	
	CO (ppm)	CO (ppm)	CO (ppm)	CO (ppm)	CO (ppm)	CO (ppm)	CO (ppm)	CO (ppm)	CO (ppm)
1	3.00	2.50	2.10	2.97	3.28	3.15	3.10	3.18	2.91
2	3.10	3.06	2.92	3.21	3.09	3.01	2.90	3.21	3.06
3	3.05	3.00	2.97	3.39	3.10	3.00	2.83	3.17	3.06
4	2.19	2.69	2.50	2.96	3.21	3.12	3.01	2.87	2.91
5	2.98	2.17	1.98	2.76	3.98	2.71	2.65	2.88	2.64
6	3.07	3.00	2.59	3.03	3.20	3.12	3.02	3.10	3.02
7	3.10	3.01	2.67	2.98	3.13	3.01	2.81	2.93	2.95
8	3.02	2.90	2.15	2.81	3.01	2.91	2.79	2.87	2.81
9	3.08	2.88	2.06	2.72	2.96	2.74	2.65	2.79	2.74
10	2.99	2.67	2.15	2.97	3.21	3.01	2.89	3.05	2.87
11	2.75	2.69	1.98	2.67	2.98	2.71	2.63	2.89	2.66
12	2.64	2.51	1.77	2.56	2.93	2.74	2.66	2.86	2.58
13	3.03	2.90	2.13	2.78	2.98	2.72	2.67	2.83	2.76
14	3.13	2.87	2.23	2.90	3.12	3.01	2.89	2.97	2.89
15	3.15	2.98	2.57	2.87	3.14	3.03	2.95	3.12	2.98

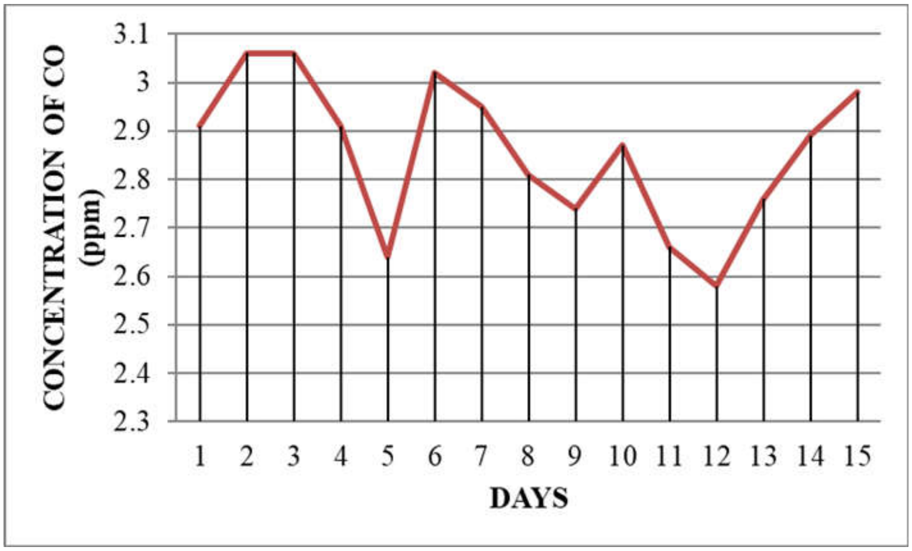

Fig 4.0 Graph showing concentration of CO in 15 days

Particulate Matter concentration

From the Table 2.0, it is observed that the particulate matter concentration ranges from 0.12 ppm to 0.16 ppm for an average of 8 hours and it lies within the threshold value of 0.20ppm as set by the WHO.

Table 2.0 PM (Particulate Matter) concentration

Day	TIME								Average of 8 hours
	8AM TO 9AM	9AM TO 10AM	10AM TO 11AM	11AM TO 12PM	12PM TO 1PM	1PM TO 2PM	2PM TO 3PM	3PM TO 4PM	
	PM_{10} (ppm)	PM_{10} (ppm)	PM_{10} (ppm)	PM_{10} (ppm)	PM_{10} (ppm)	PM_{10} (ppm)	PM_{10} (ppm)	PM_{10} (ppm)	PM_{10} (ppm)
1	0.09	0.10	0.14	0.12	0.17	0.20	0.18	0.20	0.15
2	0.08	0.12	0.16	0.14	0.18	0.15	0.12	0.14	0.14
3	0.08	0.18	0.20	0.17	0.20	0.16	0.12	0.16	0.16
4	0.07	0.16	0.20	0.16	0.19	0.16	0.13	0.16	0.15
5	0.05	0.15	0.17	0.14	0.18	0.15	0.12	0.16	0.14
6	0.01	0.15	0.19	0.15	0.20	0.14	0.11	0.15	0.14
7	0.06	0.17	0.20	0.16	0.20	0.15	0.13	0.17	0.16
8	0.06	0.13	0.17	0.12	0.17	0.14	0.12	0.18	0.14
9	0.05	0.13	0.15	0.11	0.16	0.12	0.10	0.15	0.12
10	0.09	0.14	0.19	0.16	0.20	0.17	0.12	0.17	0.16
11	0.07	0.15	0.20	0.15	0.18	0.15	0.11	0.16	0.15
12	0.06	0.17	0.20	0.13	0.18	0.14	0.10	0.14	0.14
13	0.09	0.19	0.20	0.17	0.20	0.16	0.12	0.17	0.16
14	0.06	0.10	0.15	0.11	0.17	0.14	0.09	0.12	0.12
15	0.05	0.15	0.19	0.17	0.20	0.16	0.12	0.14	0.15

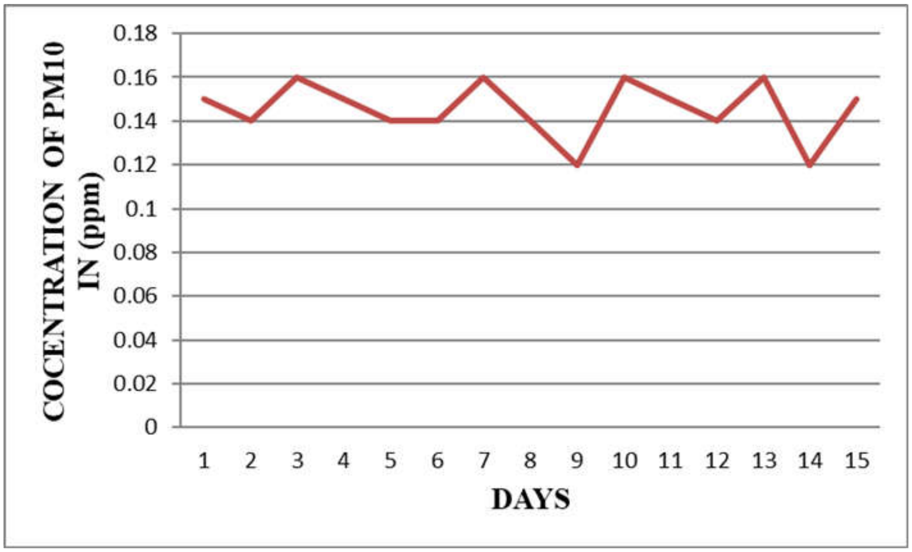

Fig 5.0 Graph showing concentration of PM in 15 days

Carbon dioxide concentration

From Table 3.0 it is observed that the carbon dioxide concentration ranges from 415ppm to 473ppm for an average period of 8 hours and it lies within the threshold value of 1000ppm as set by the WHO recommendations.

Table 3.0 CO_2 (Carbon dioxide) concentration

Day	TIME IN HOURS								Average of 8 hours
	8AM TO 9AM	9AM TO 10AM	10AM TO 11AM	11AM TO 12PM	12PM TO 1PM	1PM TO 2PM	2PM TO 3PM	3PM TO 4PM	
	CO_2 (ppm)	CO_2 (ppm)	CO_2 (ppm)	CO_2 (ppm)	CO_2 (ppm)	CO_2 (ppm)	CO_2 (ppm)	CO_2 (ppm)	CO_2 (ppm)
1	320.00	340.00	332.00	410.00	498.00	586.00	572.00	589.00	455.87
2	300.00	320.00	312.00	390.00	451.00	515.00	502.00	530.00	415.00
3	320.00	327.00	320.00	399.00	473.00	539.00	502.00	556.00	429.75
4	361.00	370.00	359.00	405.00	498.00	537.00	512.00	532.00	446.75
5	352.00	360.00	355.00	397.00	457.00	523.00	503.00	520.00	433.37
6	339.00	342.00	335.00	389.00	479.00	532.00	511.00	529.00	432.00
7	310.00	320.00	318.00	392.00	466.00	529.00	498.00	523.00	419.50
8	320.00	329.00	321.00	381.00	478.00	532.00	512.00	535.00	426.00
9	363.00	370.00	350.00	403.00	492.00	553.00	523.00	541.00	449.38
10	317.00	320.00	339.00	400.00	503.00	586.00	524.00	543.00	441.50

11	324.00	339.00	352.00	412.00	517.00	596.00	576.00	589.00	463.25
12	321.00	333.00	390.00	437.00	521.00	603.00	589.00	597.00	473.88
13	329.00	351.00	379.00	429.00	505.00	582.00	563.00	589.00	465.88
14	309.00	320.00	359.00	423.00	517.00	592.00	578.00	592.00	461.25
15	319.00	331.00	361.00	417.00	501.00	583.00	569.00	580.00	457.63

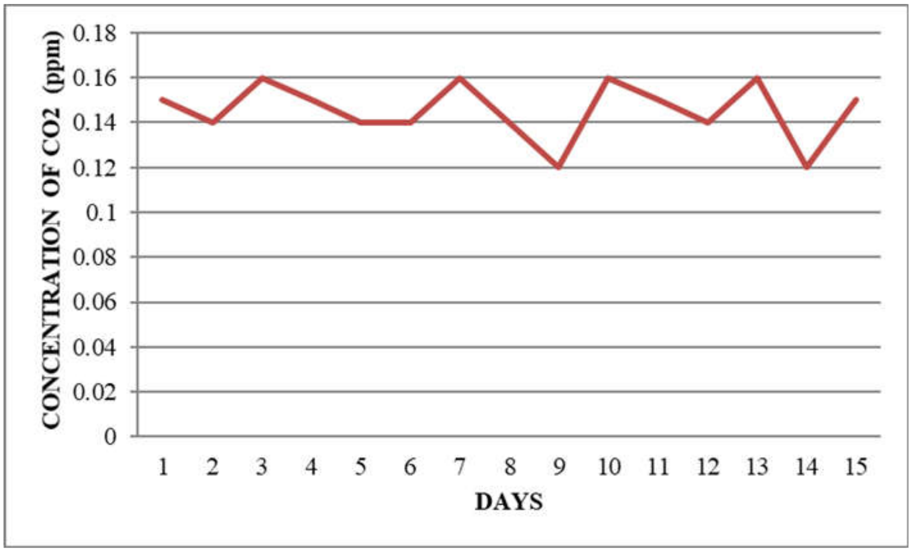

Fig 6.0 Graph showing concentration of CO_2 in 15 days

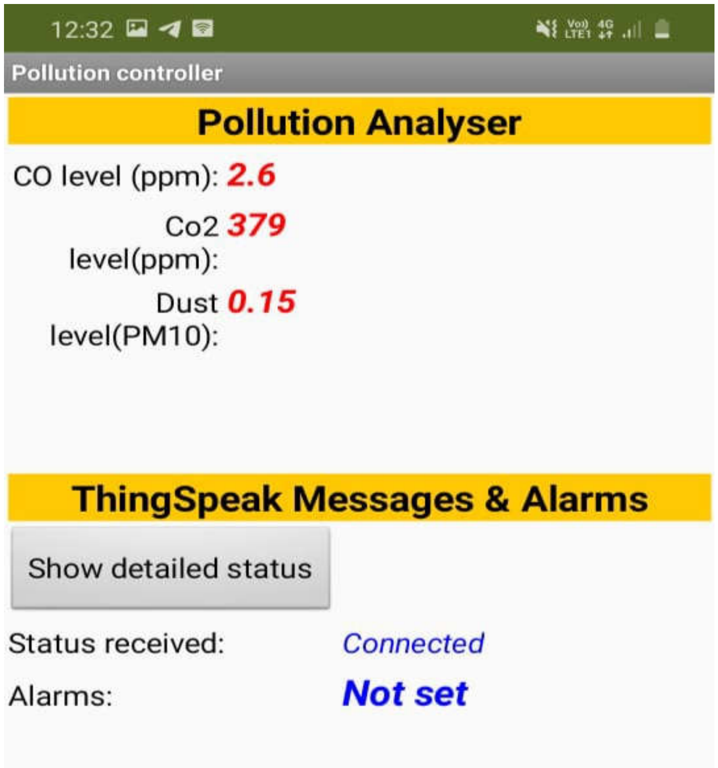

Fig 7.0 Results displayed through android app

V. CONCLUSION

This study uses wireless sensor network technologies to acquire and record monitoring data for the aim of completely automatic air-quality monitoring. On the hardware side, we integrate the NodeMCU with CO, CO_2, and Dust sensor to perform air quality monitoring tasks. The NodeMCU is able to post the monitored data in the Thingspeak cloud channels. The Thingspeak platform is able to communicate with the user by displaying the air quality data through the android app created. It also stores the data posted, for future use. And, we can also view the data in PCs, tablet, etc., through web browser. Thus, it helps even the normal people to get the knowledge of indoor air quality within their surrounding environment and to take control measures. This system may also be useful in industrial environments.

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