DOI: https://doi.org/10.33103/uot.ijccce.22.1.1

Environmental Pollution Monitoring System Based on IoT

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Abstract— *Air pollution is a common cause of health risks and also a cause of climate change, one of the most threatening problems to humans. This problem results from the abundance of automobiles, industrial production, and combustion of transportation and electricity generation petroleum products. Therefore, forecasting air pollution is necessary. In this paper, a system is proposed to monitor the level of air pollution by integrating the Internet of Things(IoT) with Wireless Sensor Networks (WSN), where pollution levels are observed in three areas in Baghdad using different types of sensors connected with ESP32 (It is the name of the chip developed by Espressif Systems) to detect Particulate Matter (PM2.5 and PM10), Nitrogen Oxides (NOx), Carbon monoxide (CO) as well as temperature and humidity to monitor indoor and outdoor air quality. Observed results are monitored by ThingSpeak, an open-source IoT platform. Success has been achieved using the ESP32 microcontroller, as the project is low-cost and uncomplicated, and pollutant measurement is accurate compared to the natural proportions of pollutants. Data display is easy and it can be monitored easily. This encourages the improvement of the model and its use in other monitoring systems.*

Index Terms— *Internet of Things (IoT), Wireless Sensor Networks (WSN), ESP32 microcontroller, ThingSpeak, Air Pollution Mentoring, Gas Sensors.*

I. INTRODUCTION

According to the World Health Organization (WHO) reports, about seven million people die worldwide due to air pollution, and studies indicate that 9 out of 10 people breathe polluted air. Air pollution causes many health problems, such as respiratory problems, premature death, and hospitalization for heart and lung diseases [1][2]. Air pollution not only affects people, but it has a significant effect on plants, as long-term exposure to pollutants causes damage to plant leaves [3].

Most of the pollutants are from stationary sources of the primary air pollutants, which are Particulate Matter of PM10 with a diameter of fewer than 10 microns and the PM2.5, which are the most dangerous because their diameter is less than 2.5 microns, which is produced from unburned fuel and process byproducts, as well as Sulfur dioxide (SO2) that is made from fuel combustion, Nitrogen Oxides (NOx), a mixture of oxygen and nitrogen reacting at high temperatures, Carbon monoxide (CO) and Ozone(O3)[4].

This work measured air quality in three main areas in Baghdad, where a sensor system was developed to measure the level of pollution in each station. Each station consists of an ESP32 microcontroller connected to it with four sensors to measure different gases, which are PM10, PM2.5, CO, NOx. These gases were chosen only because considered among the primary pollutants that affect air quality. In addition, the temperature and humidity sensor has been used to display the changes that cause Pollutants in the air with changing temperature and humidity. This paper provided helpful

Received 16/June/2021; Accepted 31/August/2021

ISSN (Print) 1811-9212 *ISSN (Online) 2617-3352*

DOI: https://doi.org/10.33103/uot.ijccce.22.1.1

information about air pollution levels and from three different stations using ESP32, whose advantages are low cost, low energy, many sensors can connect to it, ease to understand and programing.

II. RELATED WORK

In the past years, air quality monitoring has become an important matter, with the development of Internet of things systems and the development of sensors, air quality monitoring has increased. There are many researches that have studied the subject of air pollution, which will be reviewed in this part of the research.

In [5], Pasha, S. have proposed a system for remote monitoring for air quality and analyzing data using MATLAB R2016a. The researcher used Arduino-UNO and ESP8266 Wi-Fi models to send data to the ThingSpeak platform, an IoT open-source platform. The monitored data was presented in two ways, through ThingSpeak and through MATLAB R2016a plots; the researcher did not explain the method of analyzing the monitored data. Balasubramanian, C. and Manikandan, D.[6] presented an Air Quality Monitoring System (AQMS) which is based on WSN to measured concentrations of (CO, NOx, CO2and NH3) by using Raspberry Pi and to monitoring the data, they used ThingSpeak IoT platform. The results are messages sent from an account TWITTER associated with ThingSpeak. Acharya, S. et al. [7] to monitor the air quality indoor, the researcher proposed Indoor Air Quality Monitoring (IAQM) system by using Raspberry Pi. The sensing data is sent to Raspberry thought Zigbee, a robust, lightweight wireless networking protocol that builds upon the IEEE 802.15.4 standard. In this research, the relationship was shown with the increase in carbon dioxide levels with the rise in the number of people in the room. The study did not address other types of pollutants that may be more dangerous than CO2. The researcher Parmar, G., Lakhani, S. and Chattopadhyay, M. K. [8] used Raspberry pi as a base station to collect data and visualization It. Every substation consent from Serial Wireless (Wi-Fi model) and Nucleo F401RE connected to It CO, CO2 Gas seniors. This system is low cost and portable, but at the same time, it does not cover many places. To monitoring the concentration of different gases in Delhi, Kumar, S. and Jasuja, A. [9] have proposed real-time air pollution monitoring by using Raspberry Pi and Arduino UNO and sending the data to the cloud using MQTT protocol. The results were presented through the IoT platform IBM WATSON IoT. Al Kendari, A. A. and Morin, S. [10] and Rosmiati, M. et al. [11] in these two studies, researchers measure the concentration of each of the gases NO2, CO, SO2 by using Raspberry Pi and LoRa module system. In [10], the results were displayed through ThingSpeak, and in [11], the data was presented through a mobile app. The researchers Niranjan, D. K. and Rakesh, N. [12] proposed a system to analyze air pollution in real time. If the air was polluted, the system purifies the air and gives the fresh air by using some filters. Raspberry pi has been used to multiple connected sensors to it. Mahetaliya, S. et al.[13] in this study ESP32 has been used to monitor PM2.5, CO, CO2, and send data to ThingSpeak cloud to monitor and display the result. F, A. N., Raju, J. and Varsha, V.[14] they used the same method that used in last paper [13]the only difference is that they used a different platform which is Blynk Platform.

According to a survey of research articles, most researchers have employed Raspberry Pi [6-9], which has its own set of drawbacks. It can only be used locally, but if there are many IoT devices, these devices must all be connected to the same Internet network. In addition, many researchers stored data on the cloud [9][13][14] and did not take into account the interruption of the Internet, and in this case, the data was not sent. In this research, will be used three IoT devices distributed in three regions. Thus, the results will be monitored and compared to different places, using low-cost and easy-to-connect sensors. Each station sends data to the cloud through the HTTP protocol. Also, the data is stored automatically when the program is run on the SD card to save the data in the event of problems with the Internet.

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ISSN (Print) 1811-9212 ISSN (Online) 2617-3352

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III. SYSTEM DESIGN AND IMPLEMENTATION

A. Proposed System

Three Air Quality (AQ) devices for the Internet of Things (IoT) to monitor gases (PM2.5, PM10, NOx, CO), as well as a temperature and humidity sensor that is used to compare the percentage of pollution when temperature and humidity rise. AQ devices are placed in the most polluted areas in Baghdad (Jamila, Karadaa, Saidya); the reason for choosing these cities is that they are considered significant cities in Baghdad in terms of their overpopulation and their proximity to factories shown in *Fig. 1*. AQ device measures pollution levels hourly every day.

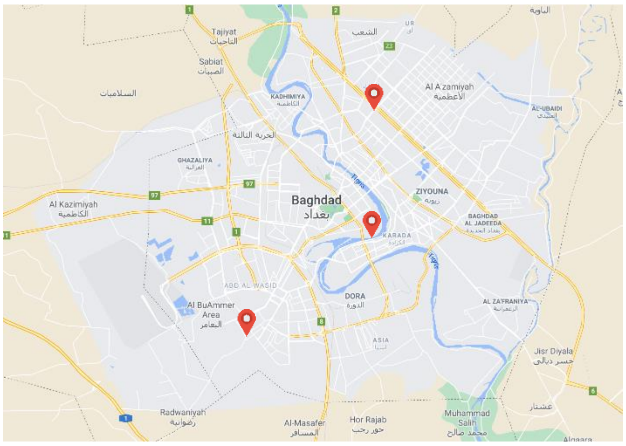

FIG. 1. AIR QUALITY DEVICE LOCATION IN GOOGLE MAP

Every AQ monitoring device contains four different types of sensors (MQ7, MQ135, Dust sensor DSM501A, DHT22) connected to ESP32; *Fig. 2* shows the proposed system's block diagram. The readings are sent from each station via Wi-Fi to the router. The last one sends it through Hypertext Transfer Protocol (HTTP) which works based on a request and response system to ThingSpeak cloud, and the ThingSpeak is an open-source platform through which sensor readings can be monitored. ThingSpeak gives each station its own ID and API so that it can communicate with the ESP32. The monitored data can also be exported as a Comma Separated Value (CSV) file to analyze and process later using deep learning techniques. In addition, to solve the problem of an internet outage, a MicroSD card has been added to store data automatically when the program is run. This piece has been programmed to accumulate data from ESP32 every hour in a CSV file.

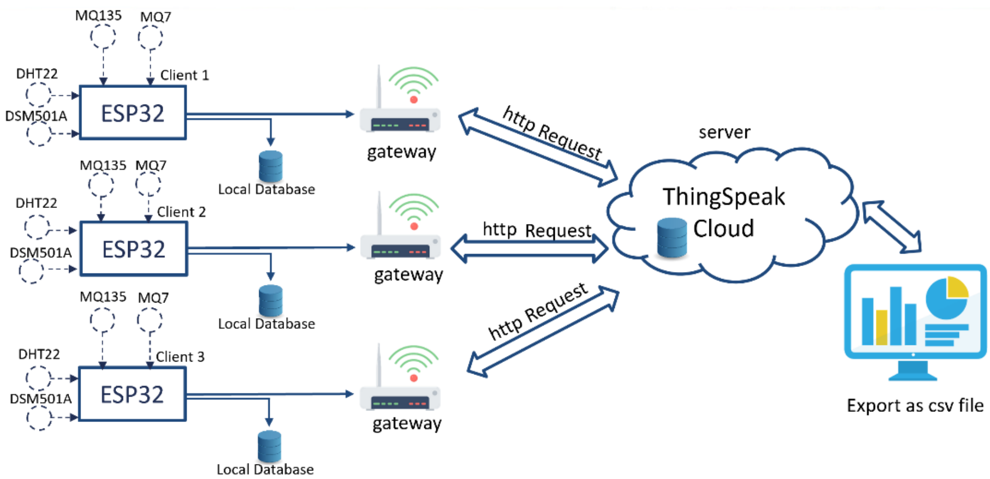

FIG. 2. BLOCK DIAGRAM PROPOSED SYSTEM

Received 16/June/2021; Accepted 31/August/2021

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B. Hardware Specification

ESP32, the name of the chip developed by Espressif Systems, is one of the most popular boards with an integrated antenna, switches and power amplifier. The ESP32 contains power management modules, filters, and a low-noise receiver amplifier. Two CPU cores can be individually controlled, and the CPU clock frequency is adjustable from 80 MHz to 240MHz [8]. This is a perfect speed for anything that requires a controller with connection options. The ESP32 can also operate reliably in an industrial environment with temperatures between -40°C and +125°C [13]. *Fig. 3* show ESP32.

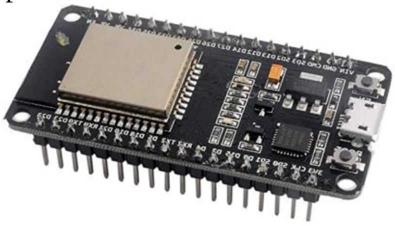

FIG. 3. ESP32

MQ-135 sensing smoke, CO2, NOx, alcohol, benzene, NH3. It has a wide detecting range, stable, high sensitivity and fast response, robust, and 5V only consumes. It can be used both analogue and digital depending on the task [12][15].MQ-7, a sensor used in detecting gas Carbon monoxide (CO) in industry or cars [13][15]. *Fig. 4* shows MQ135 and MQ7 gas sensors.

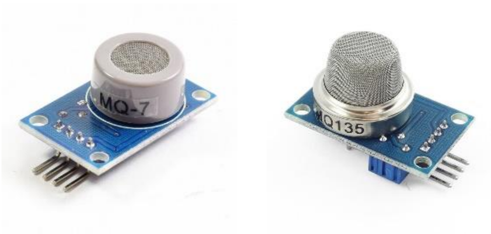

FIG. 4. MQ135 AND MQ7 GAS SENSOR

Dust sensor DSM501A is a very high sensitivity, low-cost dust sensor module. It can detect fine particles having a diameter greater than 1 micron [9]. DHT22 is a four-pin, resistive type with digital output for relative humidity and temperature [9][16]. *Fig. 5* shows Dust sensor DSM501A and DHT22 temperature and humidity sensors.

FIG. 5. DSM501A AND DHT22

Power Supply, the ESP32 has one problem, which is the power. The ESP32 can provide 3 volts, and most of the sensors used to need 5 volts. To solve this problem, an isolated power supply unit was used. This power supply is for industrial unit power supply isolation, temperature protection, overcurrent protection and short circuit protection, high and low voltage isolation shown in *Fig. 6*. The input voltage is between AC 85~370v, and the output voltage is DC 5V (+/- 0.2V) working in -20~ 60 degrees, humidity 40-90%RH [8].

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FIG. 6. EXTERNAL POWER SUPPLY MODEL

MicroSD card, micro SD card modules allow to communicate with the memory card and write or read the information. The module interfaces in the Serial Peripheral Interface (SPI) protocol, a synchronous serial data protocol used by microcontrollers to communicate swiftly over short distances with one or more peripheral devices. It can also be used to link two microcontrollers together [17][18]. Secure Digital (SD) cards can be used for data storage and data logging. Examples include data stored on digital cameras or mobile phones and data logging to record information from sensors. The micro SD card operates at 3.3V[19]. The MicroSD card model has six pins, as shown in *Fig. 7*, which is Voltage Common Collector (VCC), Ground (GND), Master In Slave Out (MISO), Master Out Slave In (MOSI), Serial Clock (SCK), Chip Select (CS).

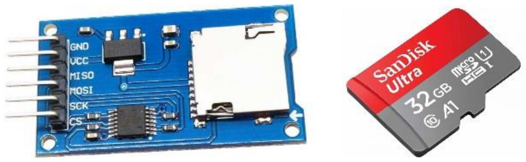

FIG. 7. MICROSD CARD MODEL AND SD CARD

The proposed air quality monitoring system is straightforward, uncomplicated and gives high accuracy. Table I shows every sensor pin connected to the General-Purpose Input Output (GPIO) in the ESP32. The VCC and GND for every sensor connect to the external power supply. *Fig. 8* show component block connections, and *Fig. 9* shows the shape of one station.

TABLE I. CONNECTION PINS

Sensors Name	Sensors Pin	ESP32 pins
DHT22	VCC	+5v
	DATA	GPIO4
	NC	-
	GND	GND
MQ135	VCC	+5V
	GND	GND
	D0	-
	A0	GPIO35
MQ7	VCC	+5V
	GND	GND
	D0	-
	A0	GPIO34
DSM501A	GND	GND
	Vout1	GPIO26
	VCC	+5V

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	Vout2	GPIO25
	Control	-
MicroSD card model	GND	GND
	VCC	+5V
	MISO	GPIO19
	MOSI	GPIO23
	SCK	GPIO18
	CS	GPIO5

*The VCC and GND connected to an external power supply
*- Not Used

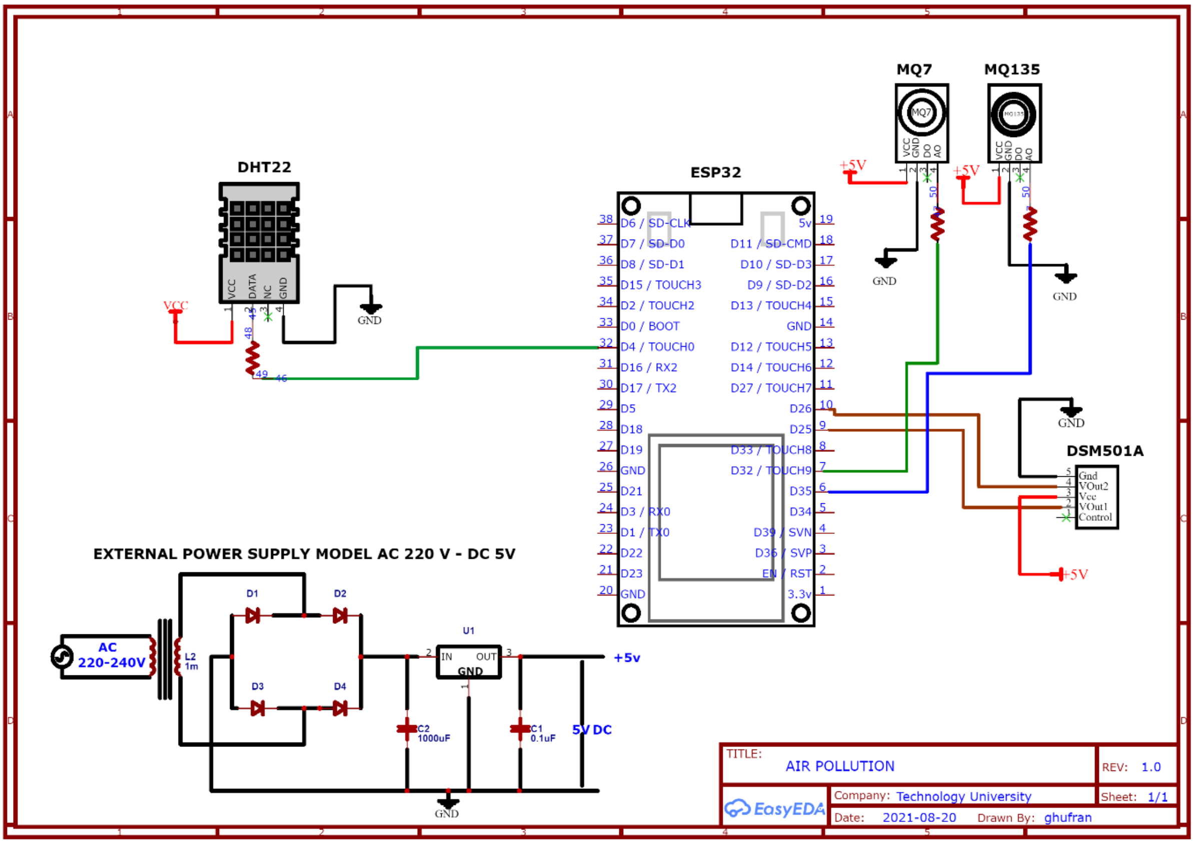

FIG. 8. COMPONENT BLOCK CONNECTIONS

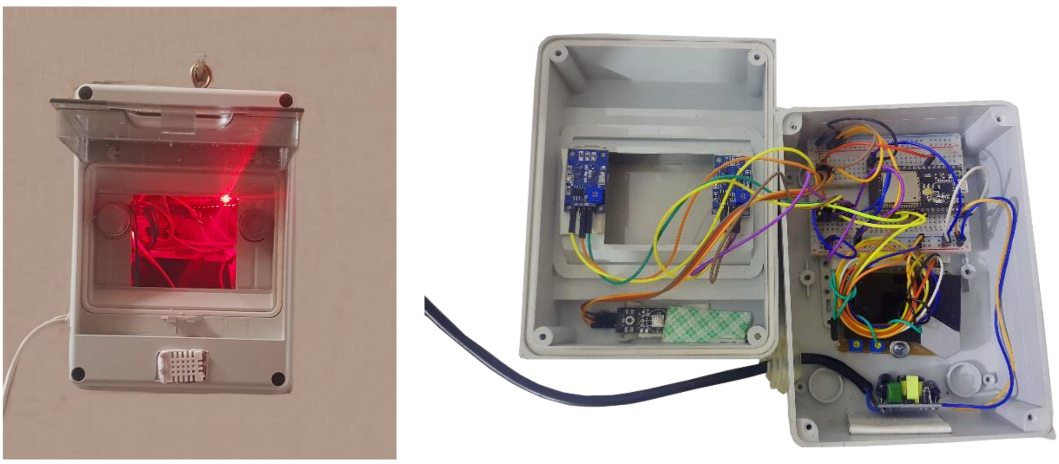

FIG. 9. FULL SET-UP FOR EXPERIMENT

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C. Software

This part explains how to program the hardware components described in the previous part. The first step needs load libraries of the sensors to Arduino IDE, which is integrated development software present for Arduino device and helps to code the Arduino microcontrollers to interface the sensors and other types of components and perform the operation on both local and global domains with the help of library functions[6]. Second, Measured Temperature and Humidity from DHT22, NOx from MQ135, CO from MQ7, PM2.5 and PM10 from DSM501A. Then, the reading is automatically sent every hour to the SD card. Next, the program is executed and visualize sensing data on the serial monitor shown in *Fig. 10*. After that, the ESP32 send HTPP request to ThingSpeak cloud through a unique API for each channel. Finally, the data will be export as a CSV file for analyzing the data in the deep learning technique in the future. *Fig. 11* shows a complete flow chart for all the processes.

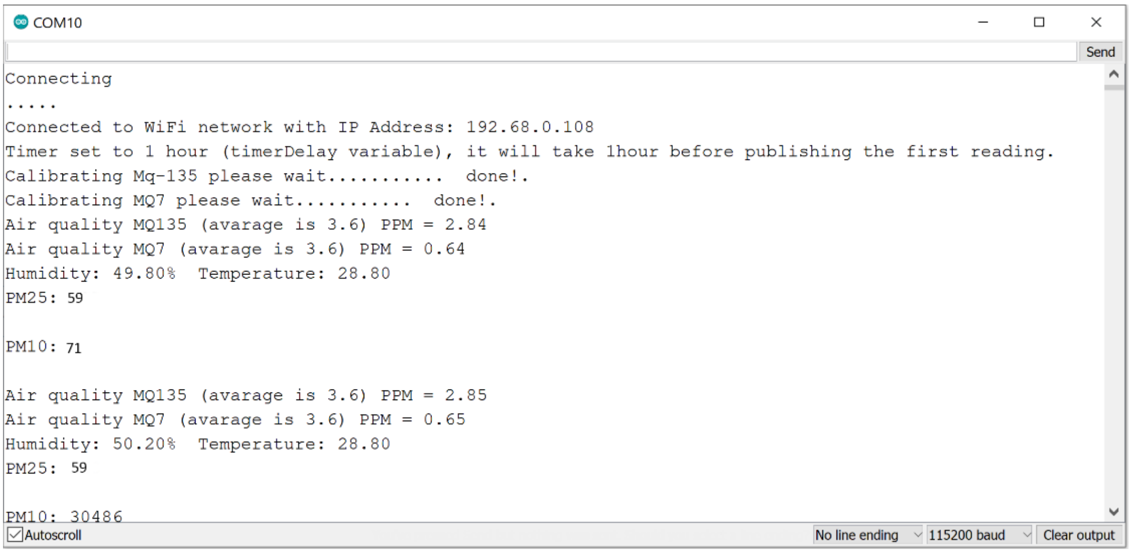

FIG. 10. SERIAL MONITOR READING

IV. RESULT AND DISCUSSION

The sensor node was deployed in different places in Baghdad for monitoring the indoor and outdoor environmental air quality. The sensor data are achieved to the ThingSpeak cloud database. *Fig. 12* shows a screenshot of the ThingSpeak monitoring dashboard for one environmental air quality station as seen the reading of every sensor is stored for every hour. Table II shows the reading of the air quality monitor data for one station for a period of six hours. And also, notice that the temperature was measured in Celsius (C), and the humidity unit is a percentage (%) in relation to CO and NOx, the unit of measurement for them is PPM (Parts Per Million). As the natural ratio of CO gas in the air is from 0-0.9, this percentage is normal, the dangerous percentage that causes health problems, starting from 10-100 [8]. NOx values range from 1 to 100 PPM [18]. The unit of PM2.5 and PM10 micrograms/cubic meter (mg/m^3) reading ranges from 0 to 500 for PM2.5 and from 0 to 600 for PM10. ThingSpeak cloud is used for saving the sensing data in online databases and for monitoring the data. The hourly data will export automatically to the local database as a CSV file.

Received 16/June/2021; Accepted 31/August/2021

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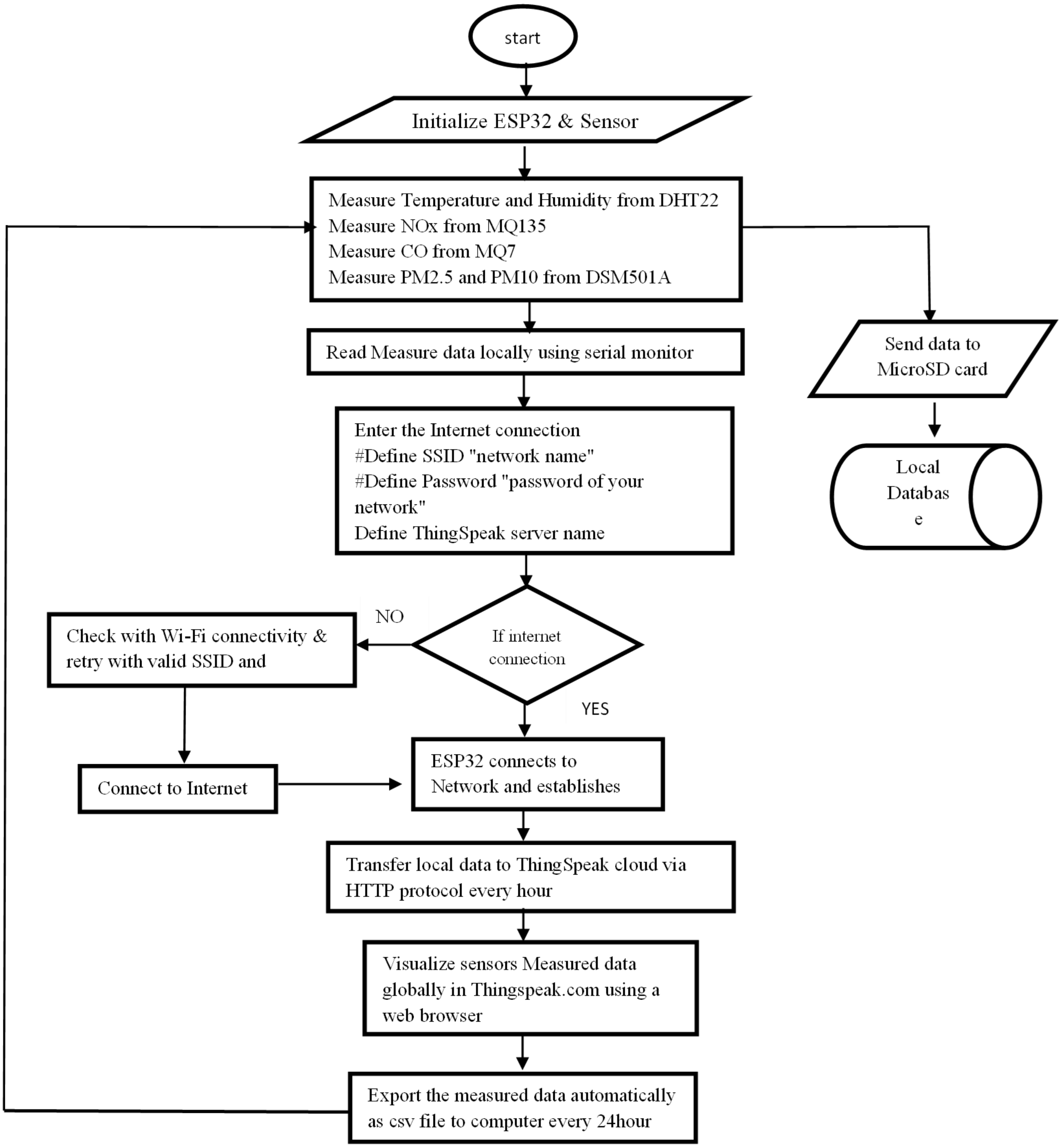

FIG. 11. FLOW CHART PROCESS FOR AIR POLLUTION MONITORING SYSTEM.

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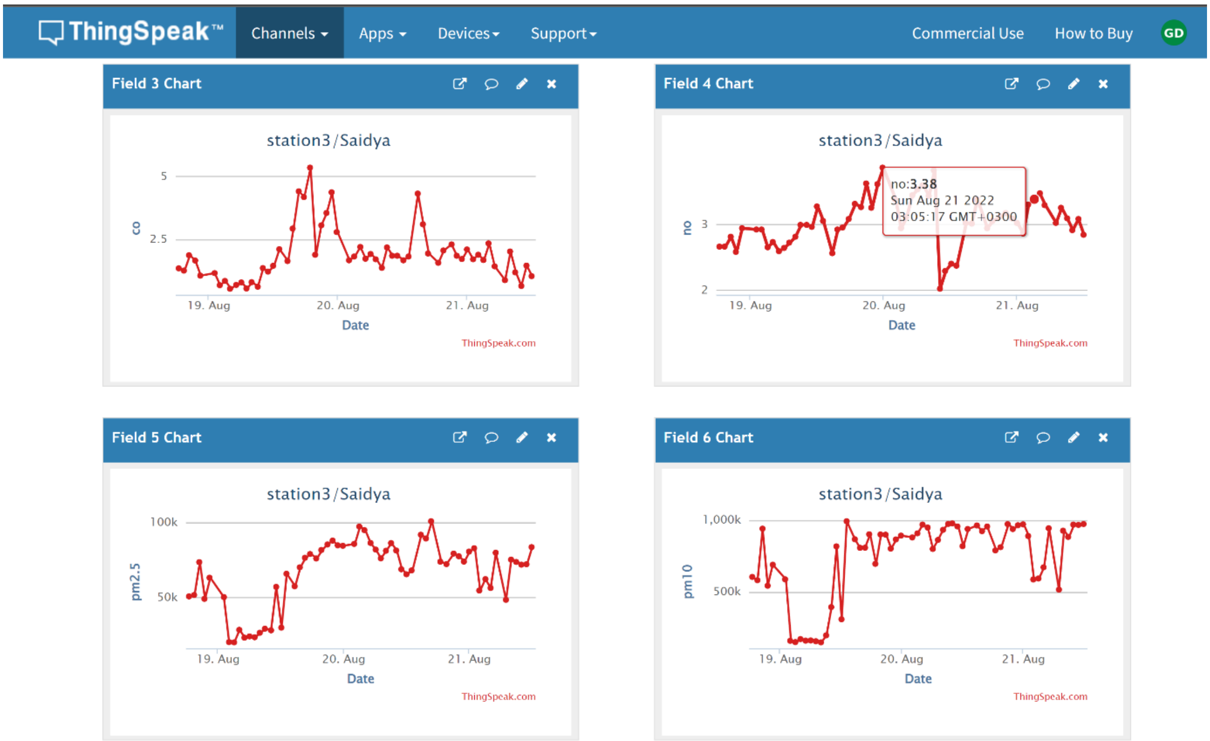

FIG. 12. SCREENSHOT OF THINGSPEAK MONITORING DASHBOARD FOR THREE DAYS.

TABLE II. READING OF SENSOR FOR SIX HOURS

Date/time	Temperature (C)	Humidity (%)	CO (PPM)	NOx (PPM)	PM2.5 (mg/m^3)	PM10 (mg/m^3)
2021-06-15-12-00	29.9	52.3	0.9	3.2	129	128
2021-06-15-01-00	29.8	50.5	0.9	3.3	138	127
2021-06-15-02-00	29.8	50.8	0.9	4.1	126	138
2021-06-15-03-00	29.5	49.7	1.2	5.7	109	159
2021-06-15-04-00	29.7	47.6	1.1	4.6	60	157
2021-06-15-05-00	29.7	45.2	1	4.1	128	184
2021-06-15-06-00	29.3	48.2	1	3.8	118	172

V. CONCLUSION

Nowadays, measuring the level of air pollution in smart cities is essential. In this paper, an environmental system for monitoring air pollution based on ESP32 has been proposed. An integrated system integrating IoT and WSN has been made; it can be said that through this integration between IoT and WSN, the air pollution monitoring system has been made more effective, and thus the main objective of monitoring air pollution has been achieved. The air through three stations in three different places was monitored. By using the traditional protocol HTTP, data are sent and received to the cloud. Through the use of the ThingSpeak platform, it became easy to monitor and analyze air quality data, as it was noted in this case that the temperature and humidity fluctuate over time. With the increase in temperature and humidity, the rise in polluted gases increases, and this affects people suffering from lung diseases as well as ordinary people.

As the next step for data processing and analysis, a deep learning system was proposed using the Long short-term memory (LSTM) algorithm, which is an algorithm specialized in analyzing time series data. Where the missing data will be processed as a first step, then the

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data will be analyzed through a deep learning algorithm to predict the pollution level for the next day, finally, the data will be visualized through a website in the form of concentrations of the level of risk starting from good to hazard.

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Received 16/June/2021; Accepted 31/August/2021

