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A Real-TimeWeb-basedAir Quality Monitoring System for Air Pollutant Detection in Ubeji, Delta State, Nigeria

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Abstract
Proper monitoring of environmental air parameters is necessary to create awareness of how some of our activities affect the quality of air around us, in addition to alerting us to take necessary precautions that will preserve our health and wellness and sustainlife. Hence in this paper, a real-timeair quality monitoring system for air pollutant detection was designed and developed. The system uses the DHT11 temperature and humidity sensor and the MQ series sensors to measure environmental air parameters like temperature and humidity, the amount of smoke present in the environment, and the concentrations of gases like CO, H_2S, and NH_3gases detected in Ubeji area of Delta State in Nigeria. The real-time sensed data is processed by the ATmega328P microcontroller,displayed on anLCD andsent via the ESP32 Wi-Fi module unit to a webserver where the data is stored. This makes it possible to have a picture of the acquired data in real time to ensure adequate monitoring of the air quality and it serves as a database for future reference.

Keywords: Wi-Fi module, pollutant detection, MQ gas sensors, air monitoring, microcontroller, webserver

1. Introduction
Air is the invisible mixture of gases that surrounds the Earth's surface, and it is one of the most important constituents of the environment. Each day, an average human being needs about 12kg of air to function properly, which is nearly 12 to 15 times greater than the amount of food consumed(Garg et al, 2006).Thus, the usefulness of air to man cannot be overemphasized.For man to benefit fully from the intake of air, the air in the atmosphere should be free from contaminants or pollutants. The current Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) for carbon monoxide is 50 parts per million (ppm) parts of air as an 8-hour time-weighted average (TWA) concentration (OSHA, 2012).Hence, an exposure beyond that limit can have adverse effect on human health.Any change in the natural composition of air that may adversely affect all living things, human life, gives rise to air pollution (Garg et al, 2006; Anjaneyulu, 2005).Any substance in the air that can cause harm to humans and the environment is known as an air pollutant (Das and Behera, 2008).

The most common air pollutants are carbon monoxide(US Environmental, 1991), ammonia(Diana et al, 2018), lead, ground-level ozone, particulate matter, nitrogen dioxide, and sulfur dioxide(Das and Behera, 2008). The contributing factors to such air pollution include vehicle exhaust aggravated by the rising car population, industrial emissions especially from petrochemical industries and cement manufacture, use of gasoline generatorsas a result of unstable power supply, use of wood as fuel for cooking and heating,etc(Ladan, 2013).To detect the presence of air pollutants and to achieve accurate and reliablemeasurement of air quality, there is need for monitoring of the environmental air parameters. Such monitoring provides raw measurements of air pollutant concentrations, which can then be analyzed and interpreted(Murad and Pereira, 2019; Khedo et al, 2010). Proper monitoring of the environmental air parameters is necessary toenable people to take the needed precautions that will preserve their health and wellness and sustaintheir lives.

Several methods have been developed to achieve air monitoring. For example, Shah et al (2018) proposed to monitor air quality over a web server using the ESP8266 WiFi module. But the measured datais not stored on a database for future reference. Also, in Okokpujie et al(2018) an air pollution monitoring system was designed using an Arduino Uno microcontroller and MQ-135 gas sensor. The measured real-time data was loggedto a remote server called "ThingSpeak".This system utilizes only one type of gas sensor to measure the air quality. Theair pollution detector presented inAhasan et al (2018)was customized using Arduino UNO, MQ-135 air quality sensor and potentiometer. The work focused on detecting smoke from different sources by using mosquito coil, motorcycle smoke and two types of cigarettes (Marlboro and Hollywood). This system does not include a webpage to enable global access to measured data. Also, Zulkifli et al (2020) proposed a smart environment monitoring system for air pollution detection in Kuantan, Pahang, Malaysia. This system allowed the measured data to be transmitted from sensors to the MySQL database by GSM SIM 900A and the output data can be seen through android mobile phone, online data display and storage. But this system experienced data delays from sensors to database.

In Veeramanikandasamy et al (2020), an IoT based real-time air quality monitoring and control system was developed to improve the health and safety of industrial workers. The results are displayed on the display interface of the ThingSpeakremote server and could be accessed via the cloud on smart mobile devices using Virtuinoandroid app.

The objective of this paper is to develop a Real-Time Web-based Air Quality Monitoring System for Air Pollutant Detectionusing Ubeji area of Delta State, Nigeria, as a case study. The system will be able to send the acquired data to a webserver where the data can be accessed online using personal computers and smartphones from anywhere around the globe via the web address. All the data collected will bestored in the web database where they can be accessed by the relevant parties for further actions. This makes it possible to have a picture of the acquired data in real time so as to ensure adequate monitoring of the air quality and it serves as a database for future reference.

2. Methodology

The developedReal-Time Web-basedAir Quality Monitoring System for Air Pollutant Detection consists of an Arduino Uno microcontroller (ATmega328P) programmed to operate the gas sensors, a website that makes it possible to have a picture of the acquired data in real time and an ESP32 Wi-Fi module unit which enables the web-based interface to communicate with the system. The block diagram of the Real-Time Web-based Air Quality Monitoring System is shown in figure 1.

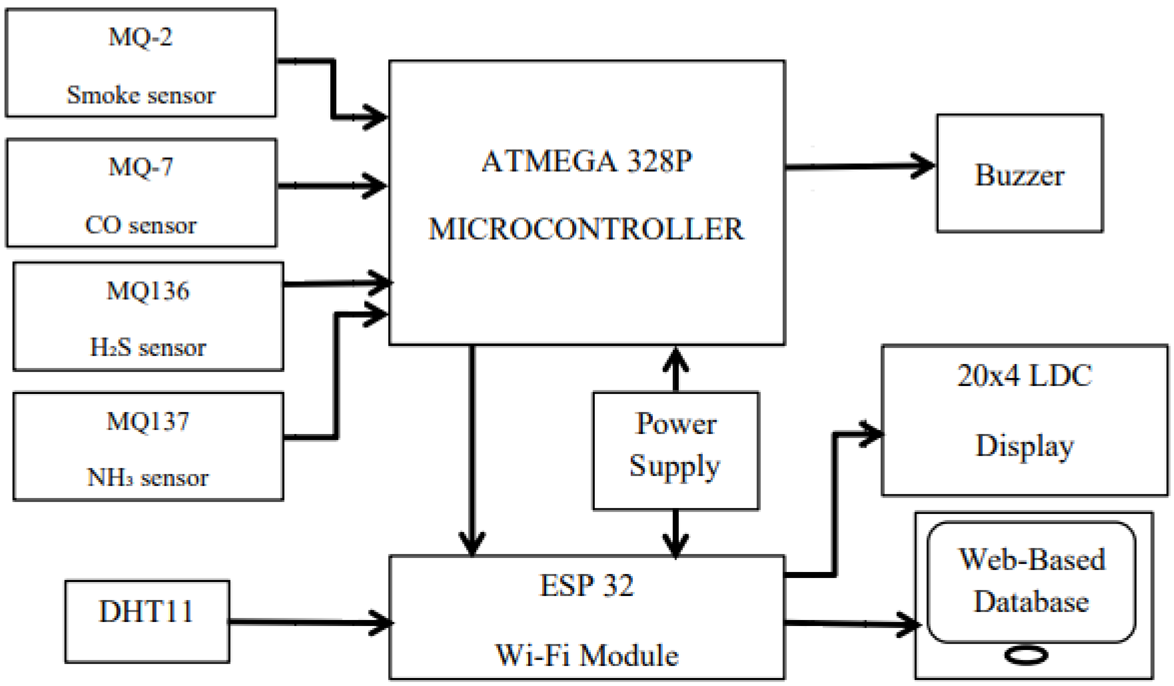

Figure 1: Block diagram of the Real-Time Web-based Air Quality Monitoring System

2.1 Microcontroller

The microcontroller acts as the brain of the entire system, where all arithmetic, logical and decision-making operations are being carried out on the system. The ATmega328P microcontroller, whose pin configuration is shown in figure 2,is operated at 5V. It has 6 analog input pins (A0 – A5) and 14 digital input/output (I/O) pins with 6 providing pulse width modulation (PWM) output. The DC current on I/O Pins and on 3.3V pin is 40 mA and 50 mA respectively. The Flash Memory is 32 KB, SRAM is 2 KB and EEPROM is 1 KB. The Frequency (Clock Speed) of the microcontroller is 16 MHz.

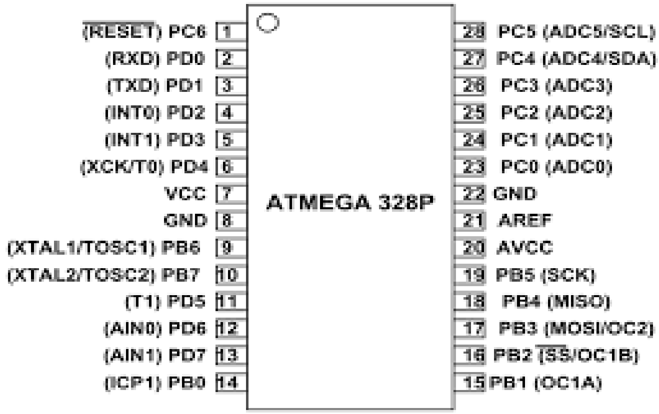

Figure 2: ATmega328 Microcontroller pin configuration

2.2 Gas Sensors

Electrochemical gas sensor is an analog sensor and gives its output in form of analog signal. This signal is fed to an analog to digital converter (ADC) which will convert it into digital form. Once the signal is converted into digital form, the microcontroller can process the digital gas signal as needed. The MQ series sensors are used to measure the amount of smoke present in the environment and the concentrations of gases like CO, H_2S, and NH_3 gases. The working principles for these sensors are similar and they can be easily implemented for the following reasons:

(i) They are rated at 5 V,
(ii) The sensor module is compatible with a 3-pin header, and
(iii) Their output is an analog signal and can be digitized by the microcontroller's ADC.

The electrochemical gas sensors that are used in this system are listed in Table 1.

Table 1: Electrochemical gas sensors

S/N	Sensor Name	Application	Picture
1.	MQ-7	CO (Carbon monoxide)	
2.	MQ136	H_2S (Hydrogen Sulfide)	
3.	MQ137	NH_3 (Ammonia gas)	

4.	MQ-2	Smoke	

2.3 Temperature and Humidity sensor

The DHT11, shown in figure 3, is a temperature and humidity sensor. Inside the DHT11, there are 3 main components, which are: a resistive humidity sensing element, a thermistor for sensing temperature and an 8-bit microcontroller, which converts the analog signals from both the sensors and sends out single digital signal. This sensor is operated at 3.5V to 5.5V and has an operating current of 0.3mA (measuring), 60uA (standby). The temperature range is 0°C - 50°C, humidity range is 20% to 80% and accuracy is ±2°C and ±5% respectively.

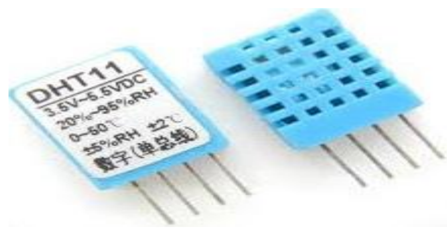

Figure 3: Temperature and Humidity sensor (DHT11)

2.4 WiFi Module

ESP32 is a series of low-power and low-cost system on chip with integrated Wi-Fi and Bluetooth microcontroller module for smart system implementation and internet of things (IoT) applications. ESP32 is dual core; this means it has 2 processors. It has Wi-Fi and Bluetooth built-in and runs 32-bit programs. The clock frequency can go up to 240MHz and it has a 512 kB RAM. It also has wide variety of peripherals availablelike capacitive touch, ADCs, DACs, UART, SPI, I2C and much more. The board also can be powered using the micro-USB connector or the VIN or 3.3V pins.There are different variations of these Wi-Fi development boards available. They offer similar capabilities but with different pinout configurations. The ESP32Wi-Fi moduleshown in figure 4 is the 30 (2 x 15) pin layout, sometimes called the DOIT Development board. It is slightly smaller, its size being 52mmx29mmx14mm.

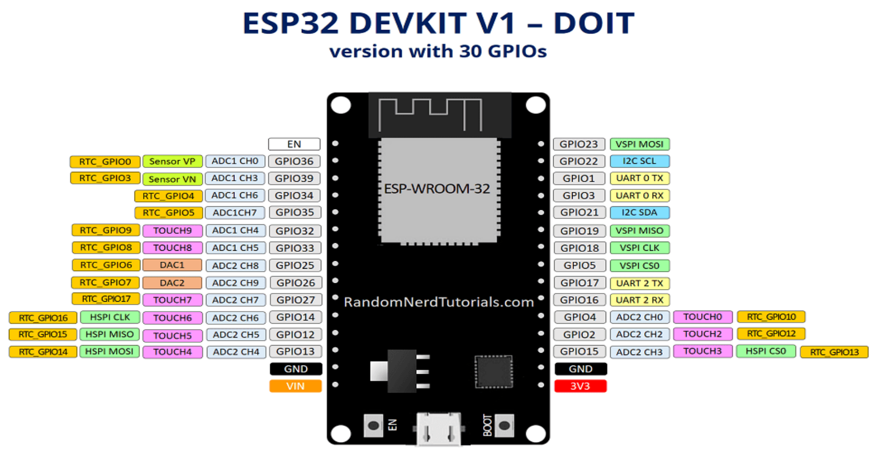

Figure 4: ESP32 Wi-Fi Module

2.5 Program Development

For the code development of the system which was performed in the simulation environment of Arduino (IDE), C language was the main programming language used. The flow chart of the program is shown in figure 5.

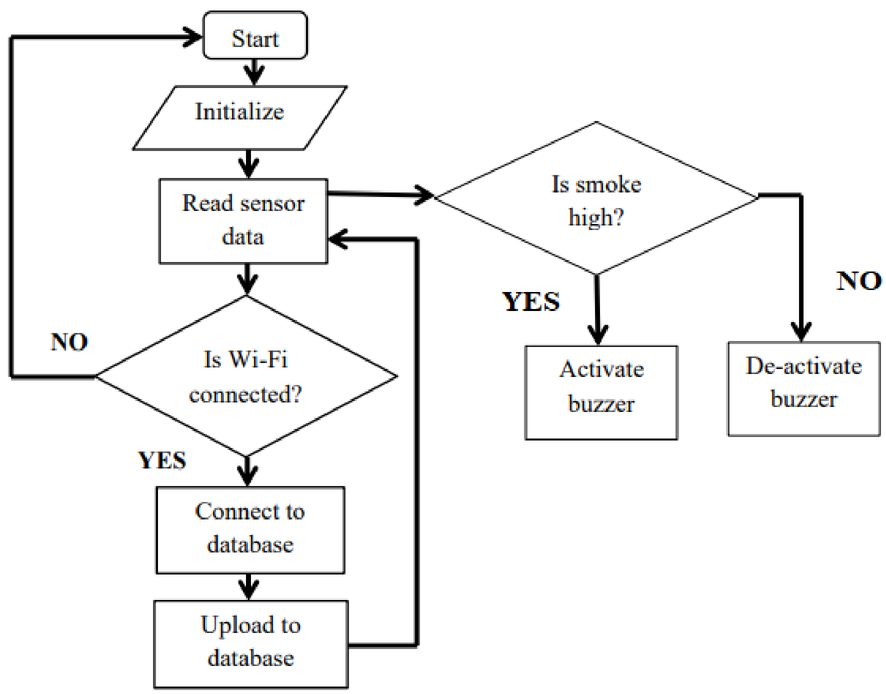

Fig. 5: Program flow chart of the real-time web-basedair quality monitoring system

2.6 Web Interface Development

The web-based interface was developed using Hypertext Markup Language (HTML), Cascading Style Sheets(CSS), JavaScript and PHP programming language with MySQL databaseengine. Figures 6 shows the web interface of the real-time air quality monitoring system, while figures 7 and 8 show the displays of the values of concentrations of CO, $NH_3$and H_2S gases, and temperature, humidity and amount of smoke detected.

The web address is: https://environ-montrg.com.ng/

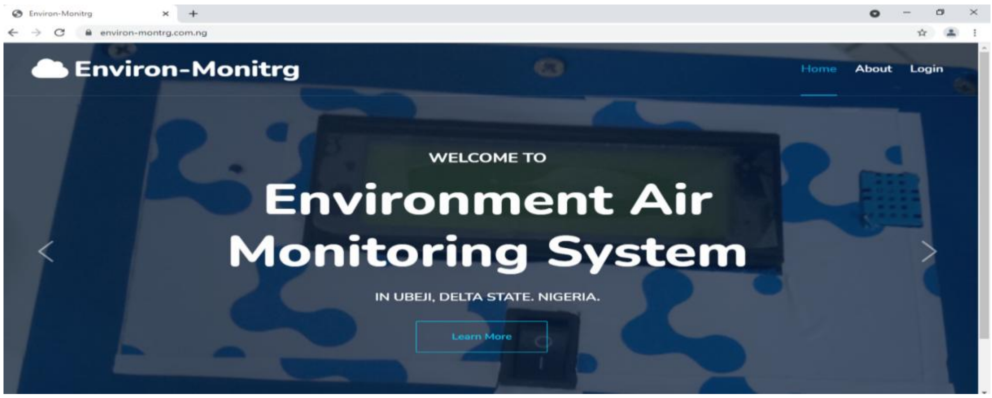

Figure 6: The web interface of the real-time air quality monitoring system

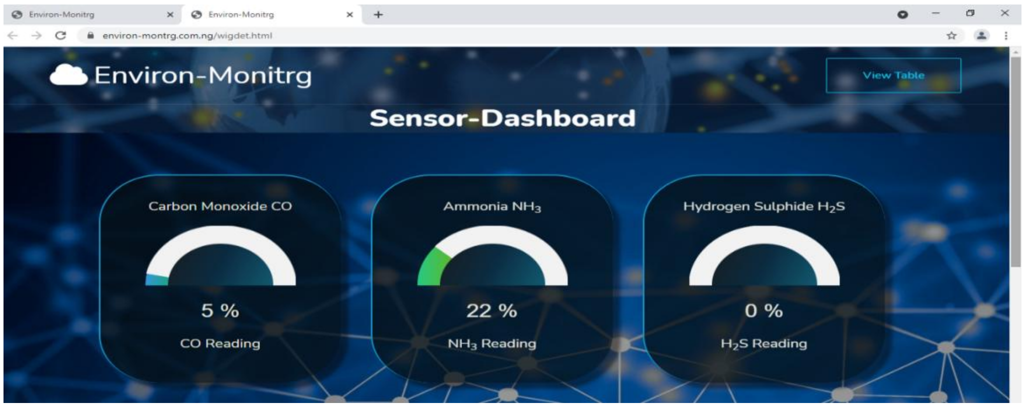

Figure 7: Display of the values of concentrations of CO, $NH_3$and H_2S gases

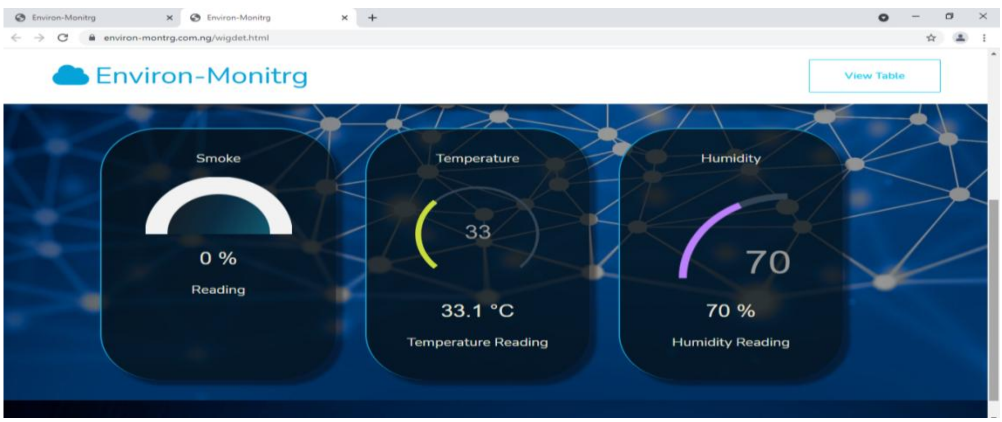

Figure 8: Display of the values of temperature, humidity and amount of smoke detected

2.7 Mode of Operation

The circuit diagram of the real-time web-basedair quality monitoring system for air pollutant detection is shown in figure 9.An AD-DC power adaptor supplies 12 VDC and it is regulated to 5 VDC by a voltage regulator LM7805 and smoothing capacitors C1 and C2 which help to filter any ripples from the power supply to the microcontroller. The microcontroller is clocked externally with 16MHZ crystal oscillator which set the frequency of operation.

This system works by collecting data of specific environmental parameters, including gas contents present in the air. The system has five fixed sensors which monitor six types of air parameters: CO, H_2S, NH_3, humidity, temperature, and smoke. Pins A0, A1, A2 and A3 of the microcontroller are programmed as input ports for the gas sensors MQ-7, MQ-137, MQ-136 and MQ-2 respectively. In general, after the sensor modules detect the environmental parameters, they generate analog signals that are digitized by the 10 bits ADC in the microcontroller.

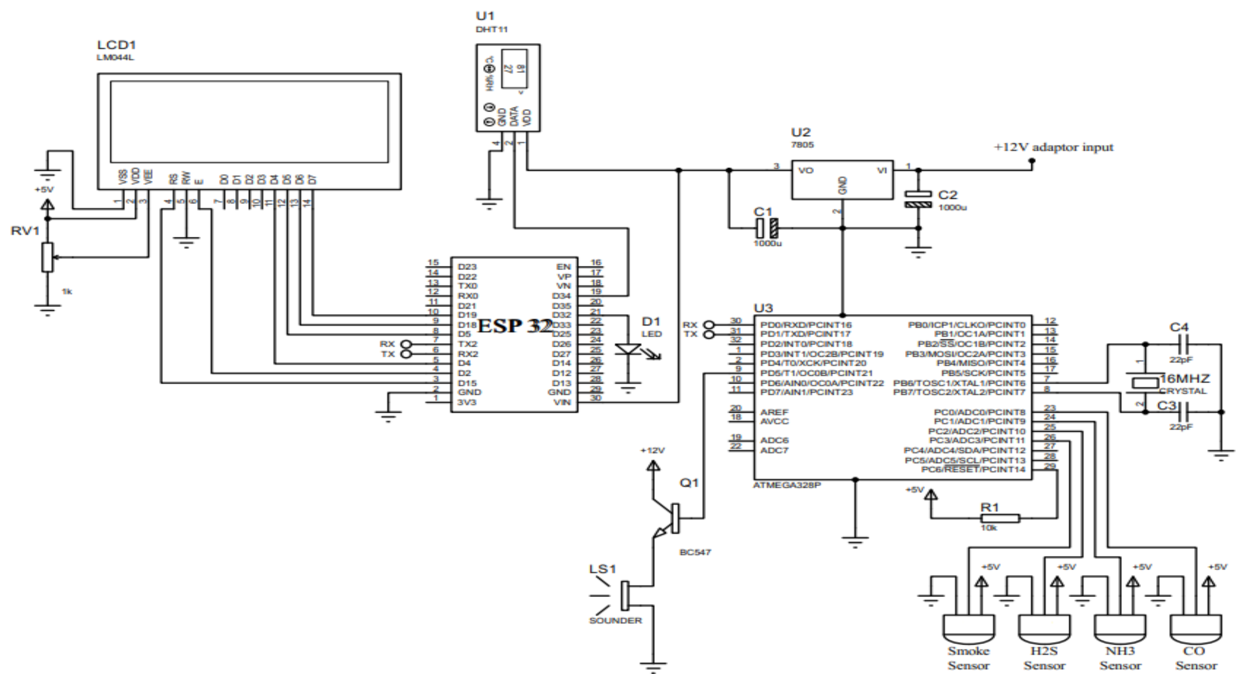

Figure 9: Circuit Diagram of the real-time web-based air quality monitoring system

The microcontroller processes all the acquired digital signals and then uses UART communication to transmit the data to the Wi-Fi module. However, pin D22 of the Wi-Fi module is programmed as the input port for the temperature and humidity sensor module. The ESP32 Wi-Fi module combines all the acquired digital signals sent from the microcontroller and from the temperature & humidity sensor, and then displays the final results on the LCD screen. The data generated by the system is transferred by the Wi-Fi module to the web server via internet. The acquired data can be accessed on the web with the address https://environ-montrg.com.ng/. Note that the LED only comes ON when data is uploaded to the web server.The result is displayed on the interface and the database of the results can be accessed simply by inputting the password.

3. Test and Results

The actual system implementation is shown in figure 10.

Figure 10: Pictorial view of the developed real-time web-basedair quality monitoring system

The results obtained for the different air pollution parameters considered (CO, NH_3 , H_2 S, Smoke, Temperature, and Relative Humidity) can be seen in tables 2 and 3. The following results were obtained atthe vicinity of Matrix Energy Limited, Ubeji, Delta State. The equipment testing is carried out for 7 minutes. As shown in Table 2, the developed air quality monitoring system was able to measure the selected air quality parameters which are CO, NH_3 , H_2 S, smoke, temperature, and relative humidity at that location within the stated period.Table 3 showsthe result when the same test was performed from a truck exhaust.

Table 2: Results obtained for the different air pollution parameters at room temperature

ID	CO (ppm)	NH_3 (ppm)	H_2 S (ppm)	Smoke (%)	Temp. (ºC)	Humidity (%)	Date	Time(GMT)
9170	0	0	0	0	39.3	44	2021-09-23	14:07:17
9171	0	0	0	0	39.3	44	2021-09-23	14:07:21
9172	0	0	0	0	39.3	44	2021-09-23	14:07:30
9173	0	0	0	0	39.3	44	2021-09-23	14:07:35
9174	0	0	0	0	39.3	44	2021-09-23	14:07:39
9175	0	0	0	0	39.2	44	2021-09-23	14:07:43
9176	0	0	0	0	39.2	45	2021-09-23	14:07:48
9177	0	0	0	0	39.1	45	2021-09-23	14:07:51
9178	0	0	0	0	39.2	46	2021-09-23	14:07:54
9179	0	0	0	0	39.1	45	2021-09-23	14:07:58
9180	0	0	0	0	39.1	45	2021-09-23	14:08:02
9181	0	0	0	0	39.1	45	2021-09-23	14:08:05
9182	0	0	0	0	39.2	45	2021-09-23	14:08:10
9183	0	0	0	0	39.1	46	2021-09-23	14:08:15

9184	0	0	0	0	39.1	45	2021-09-23	14:08:20
9185	0	0	0	0	39	45	2021-09-23	14:08:27
9186	0	0	0	0	39	45	2021-09-23	14:08:33
9187	0	0	0	0	39	46	2021-09-23	14:08:39
9188	0	0	0	0	38.9	46	2021-09-23	14:08:52

Table 3:Results obtained for the different air pollution parameters from a truck exhaust

ID	CO (ppm)	NH_3 (ppm)	H_2 S (ppm)	Smoke (%)	Temp. (°C)	Humidity (%)	Date	Time (GMT)
9219	0	0	0	20	41.4	42	2021-09-23	14:11:11
9220	0	0	0	16	41.5	41	2021-09-23	14:11:15
9221	0	0	0	15	41.6	40	2021-09-23	14:11:22
9222	0	0	0	13	41.8	40	2021-09-23	14:11:27
9223	15	0	0	27	41.9	39	2021-09-23	14:11:31
9224	17	0	0	30	42.1	39	2021-09-23	14:11:35
9225	13	0	0	22	42.3	40	2021-09-23	14:11:44
9226	8	0	0	15	42.4	39	2021-09-23	14:11:47
9227	9	0	0	20	42.6	38	2021-09-23	14:11:53
9228	18	0	0	34	42.6	37	2021-09-23	14:11:58
9229	26	0	0	41	42.7	39	2021-09-23	14:12:02
9230	25	0	0	44	42.9	39	2021-09-23	14:12:06
9231	26	0	0	49	43.2	40	2021-09-23	14:12:12
9232	33	0	0	55	43.3	40	2021-09-23	14:12:16
9233	34	0	0	53	43.4	39	2021-09-23	14:12:19
9234	37	0	0	57	43.5	37	2021-09-23	14:12:23
9235	34	0	0	58	43.6	37	2021-09-23	14:12:33

From the test results, it was observed that the real-time air quality monitoring system was able to detect the concentration of gases and amount of smoke in the environment as well as measure the ambient temperature and humidity. The sensors responded quickly, having a response time of 5 seconds. The smoke sensor sends a signal to the microcontroller to activate the buzzer when the amount of smoke in the environment exceeds the preset threshold of 80 %. Also, the LCD respondedefficiently by displaying the data received from the sensors. Afterwards, the data were uploaded to the database for record keeping and data presentation.

Conclusion

A real-time air quality monitoring system for air pollutant detection was designed and developed. The system was utilized in Ubeji area of Delta State to measure environmental air parameters like temperature and humidity, the amount of smoke present in the environment, and the concentrations of gases like CO, H_2S, and NH_3.The acquired data was uploaded to the web server and can be accessed online using personal computers and smartphones from anywhere around the globe via the web address https://environ-montrg.com.ng/.All the data collected are stored in the web database where they can be accessed by the relevant parties for further actions.This system can be implemented at home, in the workplace, oil industries, market areas, hospitals and transport companies for safety purposes.

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