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A SMART AIR POLLUTION MONITORING SYSTEM

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ABSTRACT

Air pollution affects our day to day activities and quality of life. It poses a threat to the ecosystem and the quality of life on the planet. The dire need to monitor air quality is very glaring, owing to increased industrial activities over the past years. People need to know the extent to which their activities affect air quality. This project proposes an air pollution monitoring system. The system was developed using the Arduino microcontroller. The air pollution monitoring system was designed to monitor and analyze air quality in real-time and log data to a remote server, keeping the data updated over the internet. Air quality measurements were taken based on the Parts per Million (PPM) metrics and analyzed using Microsoft Excel. The air quality measurements taken by the designed system was accurate. The result was displayed on the designed hardware's display interface and could be accessed via the cloud on any smart mobile device.

Keywords: Internet of Things, Pollution, Air, Parts per Million, Quality and Metrics.

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1. INTRODUCTION

Air is one of the essential elements of man's surroundings. The earth's atmosphere is full of air which contains gases such as Nitrogen, Oxygen, Carbon Monoxide and traces of some rare elements. Humans need an atmosphere of air that is free from contaminants. This is very crucial for human life and health. Any change in the natural composition of air may cause grave harm to life forms on earth. Air pollution is the presence of one or more contaminants in the atmosphere such as gases in a quantity that can harm humans, animals and plant [1]. Air pollutants are measured in Parts per Million (ppm) or ug/m3 [2]. Primary pollutants are released directly into the atmosphere. Secondary pollutants are produced when the primary pollutant reacts with other atmospheric chemicals [3]. Air quality affects public health. The effect of air pollution ranges from difficulty in breathing, coughing, aggravation of asthma and emphysema [4]. Polluted air can also impair visibility. Air pollution is accountable for the death of 7 million persons worldwide each year or one in eight premature deaths yearly [5]. Almost 570,000 children under the age of five die every year from respiratory infection linked to indoor/outdoor pollution and second-hand smoke [6]. Children exposed to air pollution have an elevated risk of developing chronic respiratory problems such as asthma. In the monitoring of air pollution, several researchers worldwide have developed models to monitor many of the pollution gases such as Sulphur Dioxide (SO2), Carbon Monoxide (CO), Carbon Dioxide (CO2), Nitrogen Oxides (NO) etc. This paper focuses on the design and implementation of a smart air pollutant monitoring system. It discusses how the level of pollutants in the air can be monitored using a gas sensor, Arduino microcontroller and a Wi-Fi module. The main objective of this paper is to design a smart air pollution monitoring system that can monitor, analyse and log data about air quality to a remote server and keep the data up to date over the internet.

2. RELATED WORKS

A wireless distributed mobile air pollution monitoring system using General Packet Radio Service (GPRS) sensors was reported in [7]. Advancements in wireless communication and sensor technology are rapidly changing air pollution monitoring paradigm [8]. Internet of things (IoT) also allows the creation of smart environments in which objects interact and cooperate with each other [10].

A lot of improvements have been made to existing air pollution monitoring systems. For example, [11] proposed a system for monitoring air quality at home. The system transmits sensor data wirelessly by making use of the “request and respond” protocol along with a combination of address and data centric protocols. The system monitors the indoor air quality of a home and displays the sensor reading on a screen. The researchers in [12] employed an Unmanned Aerial Vehicle (UAV) based system to monitor the air pollution in areas with poor accessibility. The system was equipped with a Pixhawk autopilot for UAV control and a Raspberry Pi for sensing and collating air pollution data. An adaptive algorithm was used to analyze the gathered pollution data. A participatory sensor system for monitoring air pollution in Sydney was proposed by scientists in [13]. In the proposed system, sensors were mounted on vehicles and a mobile application was used to upload data to a centralized repository. The system gave information to the user about their private vulnerability to pollution in the air. Recursive Converging Quartiles (RCQ) algorithm was utilized in [14] to improve the efficiency of wireless air pollution monitoring system. Recursive Converging Quartiles (RCQ) algorithm aggregates and eliminates data duplicates by removing invalid readings. This saves energy. The system consisted of sensor nodes and wireless communication links to a server. The sensor nodes collated data automatically and passed it on through the network to the server. The sensor nodes automatically forwarded data measured to the server the moment they received instruction from the system to do so. The k-means clustering algorithm for analyzing air pollution was proposed by the authors in [15]. A comparative study was made between the proposed k-means algorithm and the probabilistic fuzzy c-means (PFCM) clustering algorithm in terms of exactness and process period. The authors submitted that the proposed K-means clustering algorithm yielded exact values within a fewer process period in comparison to other existing techniques. The authors in [16] proposed a model that showed the concentration of air pollutants in real-time. An optimal Wireless Sensor Network (WSN) was proposed in [17] for monitoring the level of contaminants in the air. The system was enhanced by utilizing a flow concept that gave a combined formulation of coverage and connectivity. The probabilistic sensors taken into consideration could handle multiple weather scenarios. There was also need for the flow constraints to be formulated to ensure that the network remained conservative. A sensor-based system to monitor the air pollution in [18] employed the use of Internet of Things (IoT) to enable data about air pollutants to be monitored online. When the pollutants' level in a locality exceeded the standard air quality index, the sensor-based system shared the information via SMS with the public. An ambient real-time air quality monitoring system that consisted of numerous distributed monitoring stations that were connected wirelessly to a backend server using machine-to-machine communication was explained in [19]. The backend server assembled real-time data from the stations and reproduced them as information that can be delivered to users through web portals and mobile applications. However, cooperative, distributed, and energy-efficient communication protocols are required. Geographical search on social networks was used by the researchers in [20] to gauge the level of pollutants in the air. The assumptions made were evaluated on three continents of the planet. A minimum increment in the number of air pollution related posts meant a rise in air pollution in that environment. Measured data was acquired online while processing and statistical analysis was performed offline. The use of Supervisory Control and Data Acquisition (SCADA) for air pollution monitoring was proposed in [20]. It enabled the acquisition and statistical processing of measured data in real time. The smart SCADA made results available to users instantly. An air pollution and noise monitoring system that was IoT based was proposed by [22]. Raspberry Pi was used to detect the noise and the level of air pollution in the environment. IoT based on metamorphic changes with a sensing device was proposed by [23]. The system consisted of a Raspberry PI module and sensors connected to a computer system to monitor the fluctuation of two or three parameters of Carbon Monoxide (CO) and other gases from the normal level. The results showed that real-time air pollution data can be accessible on a web page from anywhere within the network's range. However, the parameters considered are not sufficient to give an accurate prediction of air pollution over a long time. The researchers in [24] also designed an IoT based air pollution monitoring system over a web server that triggered an alarm whenever the air quality drops below the threshold. The model was able to show the air quality in parts per million on a Liquid Crystal Display (LCD) screen as well as on a webpage to achieve real-time monitoring. In [25], an IoT based air pollution technique using Single Board Computers (SBC) which integrates IoT with wireless sensor network (WSN). Processing complexity was reduced with the use of SBC and this made the alerting process smart and in real-time. Results showed that the proposed system offered a low-cost implementation that was very flexible and scalable. However, the model does not have a wide coverage area. Arduino microcontroller based on IoT technology to monitor air pollution was used in [26]. The MQ135 gas sensor was used to sense different type of dangerous gases and the Arduino microcontroller controls the entire process. Software technologies like image processing and machine learning were used in [27] to monitor some parameters and big data techniques was used to analyse sensor values for the prediction of future values. The system was very stable and effective. However, there was a need to make the system auto-communicative to reduce processing time. The system can also be automated for real- time monitoring which will help to increase industrial output [28-31]. A real-time air pollution monitoring system in [32] employed IoT based on a large number of sensors. The obtained data was analyzed using neural network. The system achieved a better monitoring accuracy due to its use of a large number of sensors. The use of IoT devices enabled the air pollution monitoring system to be smart and scalable.

3. METHODOLOGY

The model was designed using an Arduino Uno microcontroller, Wi-Fi module 8266, MQ135 Gas Sensor and a 16 by 2 liquid crystal display (LCD) Screen. Figure 1 shows the proposed system overview and the functional block diagram is depicted in figure 2. The proposed flow chart is presented in figure 3.

The system overview procedure was classified into Five (5) layers as shown in figure 1. The first layer was the environmental parameters which are obtained by measurement. The second layer was the study of the characteristics and features of the sensors. The third layer was the decision making, sensing, measuring, fixing of the threshold valve, periodicity of sensitivity, timing and space. The fourth layer was the sensor data acquisition. The fifth layer was the ambient intelligence environment. The sensor collected data when operated by the microcontroller and forwarded it over the internet for analysis via the Wi-Fi module. Users were able to monitor measured parameters on their smartphones. The design specification of the proposed system is described in Table 1.

Table 1 The Design Specification

S/N	Component Required	Quantity
1	Arduino Uno	1
2	MQ 135 Sensor	1
3	16 by 2 LCD Screen	1
4	ESP 8266 Wi-Fi Module	1
5	Bread Board	1
6	10K Potentiometer	1
7	1k ohm Resistor	1
8	220 Ohm Resistor	3
9	Connecting Wires	Any Amount

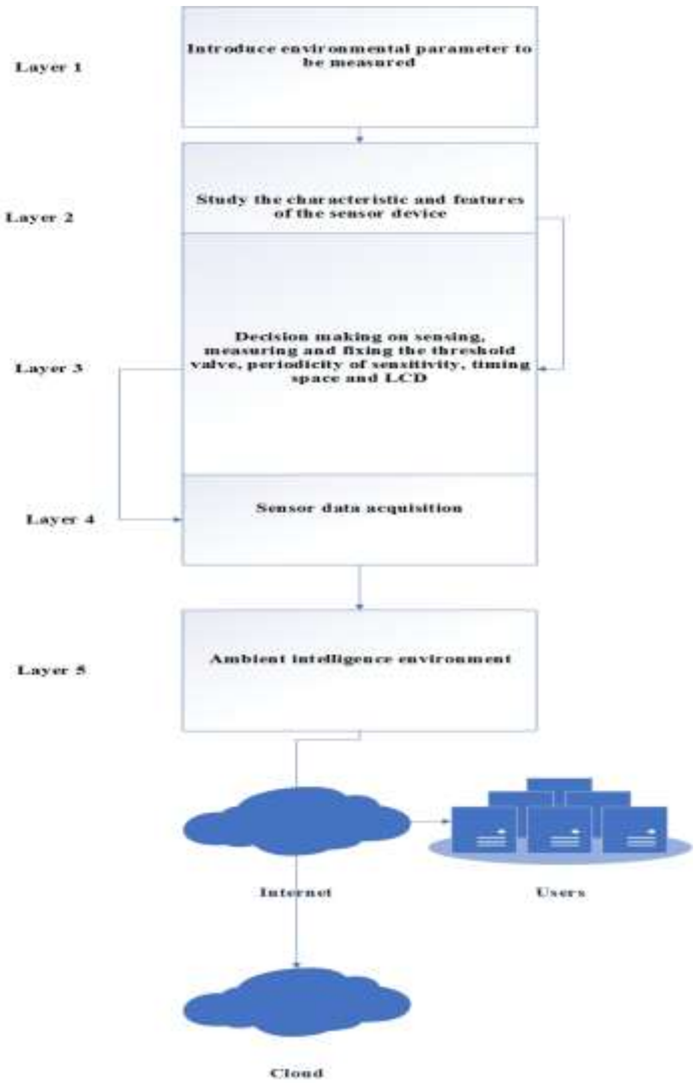

Figure 1 Overview of the Proposed System

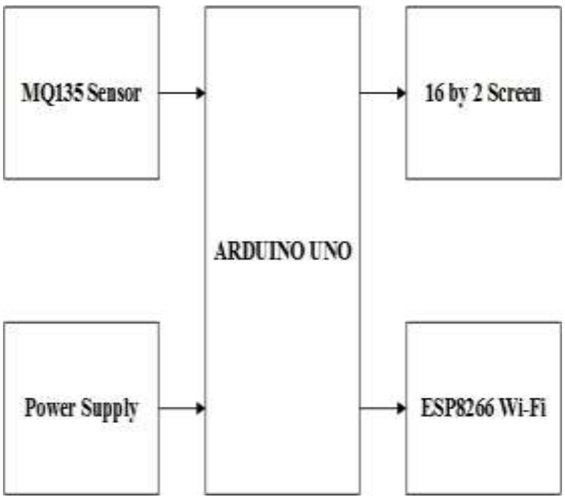

Figure 2 Block Diagram of the Proposed Air Pollution Measuring System

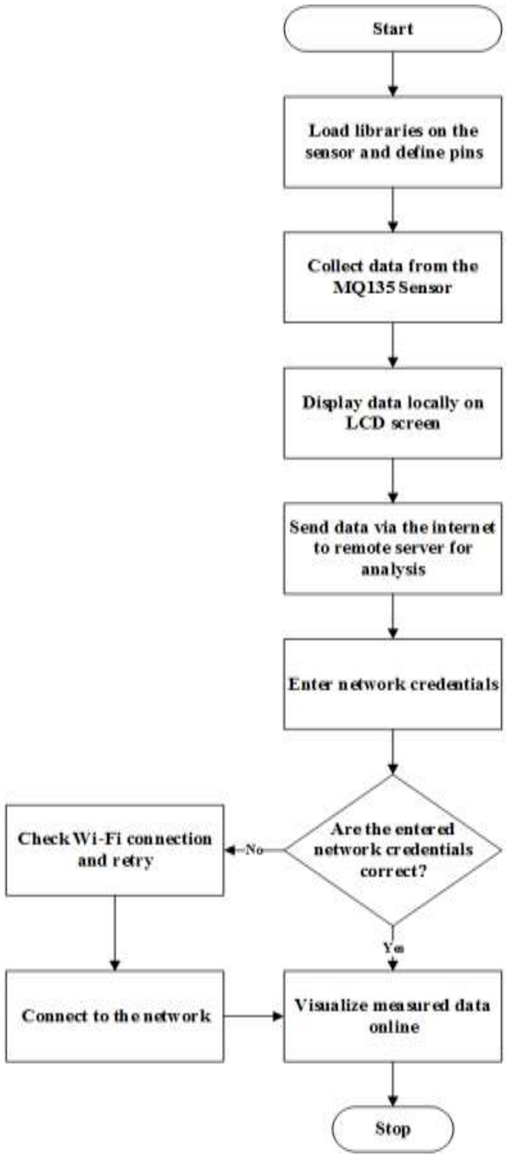

Figure 3 Flow chart of the proposed system

3.1. Working Principle of Proposed Model

As described by Figure 3, the library in the Arduino was loaded and a message was sent to the LCD. Air quality data was collected using the MQ135 sensor. The calibrated sensor made the analog output voltage proportional to the concentration of polluting gases in Parts per Million (ppm). The data is first displayed on the LCD screen and then sent to the Wi-Fi module. The Wi-Fi module transfers the measured data valve to the server via internet. The Wi-Fi module is configured to transfer measured data an application on a remote server called “Thing speak”. The online application provides global access to measured data via any device that has internet connection capabilities. Data collected from the sensor was converted into a string and used to update the information sent to the remote server.

3.2. Mathematical Analysis of Proposed Model

The level concentration of pollutants in the air is measured in parts per million (ppm) or percentage.

Conversion factors include the following:

1 ppm = 1.145 mg/m3

1 mg/m3 = 0.873 ppm

1% = 1/100

1 ppm = 1/1000000

1 ppm = 0.0001%

Table 2 shows PPM to percentage conversion.

Table 2 PPM to Percentage conversion

Parts per Million (ppm)	Percent (%)
0	0
5	0.005
50	0.005
500	0.05
1000	0.1

4. RESULTS AND DISCUSSION

The online application used to analyze air quality data got from sensors in this proposed system was "Thing-speak". Thing-speak is an open source internet of things application programming interface used to store and retrieve data from interconnected things using the hypertext protocol over the internet or via a local area network. It also provides access to a broad range of embedded devices and web services. This enables the creation of sensor logging applications that can be updated regularly. Figures 5-10 show the results of various pollutants that were obtained.

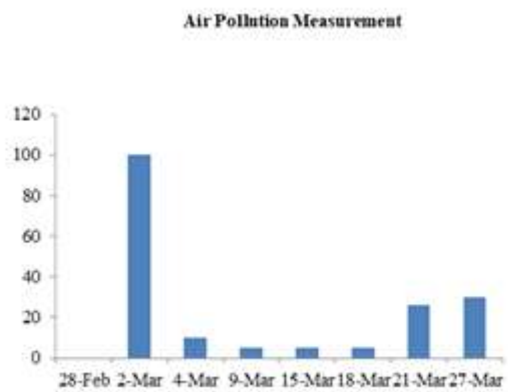

Figure 5 Air Quality on Selected Days with an Aerosol as Sample Pollutant

Figure 5 shows that there was a minimal level of pollutant before the sensor started reading the sample aerosol. However, when the sensor detected the aerosol, the air quality dropped rapidly from 0 to 100 ppm. After several readings on different days, it can be seen that there was significant reduction of the sample aerosol level in the air by the 27th of March.

Figure 6 Air Quality on Selected Days with Dust as Sample Pollutant

Figure 6 shows that the dust level in the environment was at the minimum on the 28th of February but increased gradually with each passing day. On some particular days, there was a gradual and on other days there were no changes in the quality of the air. The level of the dust measured in the air is dependent on a lot of factors that are beyond the scope of this work.

Figure 7 Air Quality on Selected Days with a Gas as Sample Pollutant

The results from Figure 7 show the air quality level was significantly low in comparison to the previous pollutants mused. It can be seen the air quality level dropped rapidly after only a few days of taking measurements. This is so because gases are high level air pollutants.

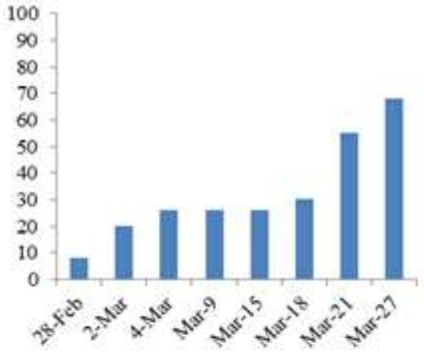

Figure 8 Air Quality on Selected Days with Smoke as Sample Pollutant

Figure 8 shows that the air quality decreased gradually from 8 ppm to about 70 ppm depending on the level of concentration smoke in the air.

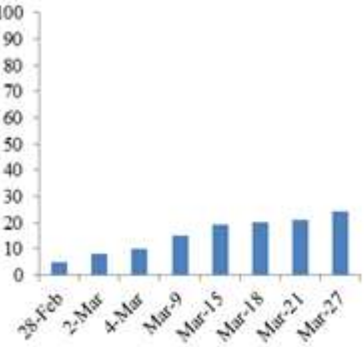

Figure 9 Air Quality on Selected Days with Biogas as Sample Pollutant

"Thing-speak" was configured to receive data from a remote system. The data was analyzed and published in the form of a scatter line graphs or bar charts on a channel. The channel corresponds to the air quality level as shown in Figure 10. The channel receives update every time from the remote sensor via the internet and represents the data received as a scatter line graph online.

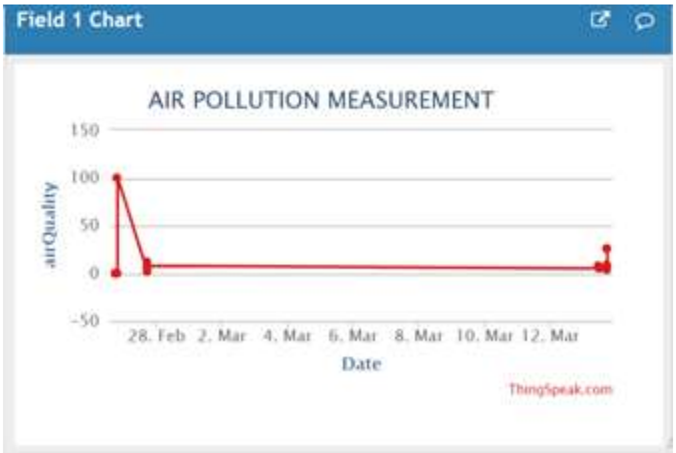

Figure 10 Air quality measurement as seen online

The visual representation of data on "thing-speak" corresponded with the measured air quality. The rate at which data displayed on "Thing-speak" changes was dependent on the network traffic and speed of internet connection. The status of the air quality can be accessed at any time, with automatic updates occurring at defined time intervals.

5. CONCLUSION

This research proposed a smart air pollution monitoring system that constantly keeps track of air quality in an area and displays the air quality measured on an LCD screen. It also sends data measured to the "Thing speak" platform. The system helps to create awareness of the quality of air that one breathes daily. This monitoring device can deliver real-time measurements of air quality.

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