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## IOT (INTERNET OF THINGS) REAL-TIME SMART MONITORING OF ENVIRONMENTAL PARAMETERS USING ARDUINO UNO REV. 3

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### ABSTRACT

Atmospheric pollution affects our daily activities and quality of life. Laying a threat to the ecosystem and the quality of life on the planet. It has become imperative to monitor air quality. Due to an increase in industrial activities. People need to know the extent to which their activities in real time affect air quality. This project proposes an air pollution monitoring system. The system was developed using the Arduino One Anu microcontroller, the SQM135 and MQ6 gas sensors, DHT11 for temperature and humidity and other circuit elements. This atmospheric pollution monitoring system has been designed to monitor and analyze the air quality in real time and record data on a remote server, maintaining the data updated via the Internet. The air quality measurements were based on parts per million metrics (ppm) and analyzed using Microsoft Excel. The air quality measures taken from the designed system have been accurate. The result was shown in the designed hardware display interface and can be accessible via the Cloud (NGROK server) on any smart mobile device.

### 1. INTRODUCTION

The atmosphere is a complex dynamic natural gas system, vital to life on Earth. Air pollution refers to a mixture of chemical substances, particles and biological materials in the atmosphere, causing discomfort to humans or other organisms, endangering the natural or built environment. Indoor air pollution and urban air quality are listed as the two most serious pollution problems in the world in the Blacksmith Institute's 2008 report on the most polluted places [1]. The substances in the air that can cause harm to humans and the environment are called air pollutants. These contaminants can be in the form of particulate matter (PM2.5 and PM10), droplets or gases. They can be natural or artificial. Pollutants can be classified as primary or secondary. Major pollutants are usually emitted directly from the process, such as ashes from volcanic eruptions, NO<sub>x</sub> and CO in motor vehicle exhaust, or SO<sub>x</sub> from factories. The secondary pollutants are not discharged directly. Instead, they are formed in the air when major pollutants react or interact. An important example of secondary pollutants is ground-level ozone, which is one of many secondary pollutants that constitute photochemical smog.

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Air pollutants come from various sources including residential buildings, commercial establishments, factories and vehicular emissions [2]. The emission of fine PM resulting from the combustion of fossil fuels in residential, commercial, industrial, and transportation sectors has been found to have adverse effects on human health [3], especially in low- and middle-income countries [4]. People's physical health and mental well-being are dramatically impacted by air pollution, and prolonged exposure raises the risk of cardiovascular and respiratory conditions [5]. Furthermore, based on projections provided by the WHO, it is estimated that approximately 4.2 million individuals are expected to die annually due to the adverse effects of air pollution [2]. Besides harmful impacts low air quality on human health, elevated airborne PM lead to major environmental issues including reduced visibility, irregular rainfall patterns, acid rain, global warming, and other phenomena related to climate change.

Air Quality points to the purity of the ambient air and its health consequences. The standard measure is Air Quality Index (AQI). Air quality has become a critical concern in recent years due to its impact on public health and the environment. Poor air quality is associated with increased morbidity and mortality, with a large proportion of urban populations exposed to air that does not meet health standards [6]. Climate change exacerbates this issue, affecting the levels of key pollutants which have serious health implications [7]. Furthermore, studies have shown that air pollution is responsible for respiratory problems, including bronchitis, pneumonia, emphysema, asthma, and lung cancer [8, 9, 10]. Research in air quality and weather measurements are becoming more relevant since weather affects almost all aspects of our everyday lives. It is noteworthy that in most developing countries, there is a dearth of such studies due to lack of monitoring devices as well as technical expertise to maintain them. The need for affordable equipment to generate ground measurements is critical in the prediction of adverse weather to improve agriculture and other aspects of human endeavors. Air pollution and its consequences are also of particular concern in urban areas heightened by rising population.

The health implications of poor air quality are recognized by professionals and the general public alike and these concerns have driven the proliferation of cheap sensors that can be used beyond research centers. Conventional air quality monitoring systems are expensive and require advanced equipment and expertise. Government agencies deploy expensive instruments in research institutes for reliable air quality measurements. These are often located in cities and cannot cover large areas. Low-cost sensors have emerged on the market in recent years as a consequence of the development of technology, presumably also because of demand or the growth of a market for small-scale measurements. Citizens are increasingly using these sensors to monitor the air quality in their environs. The use of low-cost sensors can morph into a dense regional network of measurements. Indeed, low-cost sensors can be used as a complement to monitor the air quality of a region and not as a replacement for expensive scientific equipment [11]. Reliability of low-cost sensor measurements is now an ongoing area of research and study in the scientific community. The development of low-cost air quality monitoring systems has accelerated because of accessibility, affordability, and potential for broad application in a variety of settings. These Internet of Things (IoT)-based devices allow for real-time data analysis, monitoring, and decision-making to improve air quality, especially in locations with limited resources or high risk. IoT-based devices are easier to install and maintain with inexpensive sensors. However, the accuracy of inexpensive sensors is less reliable and requires regular calibration than that of more expensive options. Uploading measurements to cloud-based system can provide additional benefits of improved data storage, processing capability, and real-time data sharing with the general public, urban planners, and environmental organizations. This increases the system's flexibility and adaptability to a wider range of air quality monitoring requirements, such as tracking urban pollution and evaluating the indoor air quality of public spaces. The rapid increase of low-cost air quality sensors in recent

years is due to their ability to track local air pollution events in real-time. These affordable sensors enable widespread deployment, fostering dense networks that offer high spatial and temporal resolution [12].

IoT solutions offer several advantages including continuous data collection; lower deployment and maintenance costs through the use of low-cost sensors; improved scalability for wide-area monitoring; and enhanced predictive and analytical capabilities. IoT systems particularly beneficial for the growing demands of modern air quality management, especially in developing nations with few monitoring networks and inconsistent data quality, which hinders accurate air quality assessment [13, 14]. While delivering valuable data for various applications, the technology faces challenges such as the need for continuous calibration, sensitivity to environmental conditions, and potential limitations in meeting regulatory standards [1].

In this study, we developed an Arduino-based system configured to monitor air quality parameters such as humidity, temperature, and PM (particle matter) levels. This research underscores the significance of utilizing IoT technology for air quality monitoring and highlights opportunities for enhancing existing monitoring methodologies. This will generate reliable data for air quality services to enhance economic efficiency and productivity.

**Description of the Air Quality Monitoring Device**

The block diagram of the overall device is shown in Figure 1. The diagram consists of the Microcontroller; Arduino Uno microcontroller, sensor; DHT11 digital temperature and humidity sensor, MQ136 gas sensor, MQ6 LPG sensor, Wi-Fi module and other materials and circuit elements like connectors, resistors; pot resistor and fixed resistor and power source. The device is constructed and implemented in such a way that it is easy to operate and measure air quality parameters and other metrological variables such as temperature and related humidity, these measured air quality parameters and meteorological variables values are displayed via the LCD, the battery 15 volts is the energy source to this device the USB port can also serve as the source of energy.

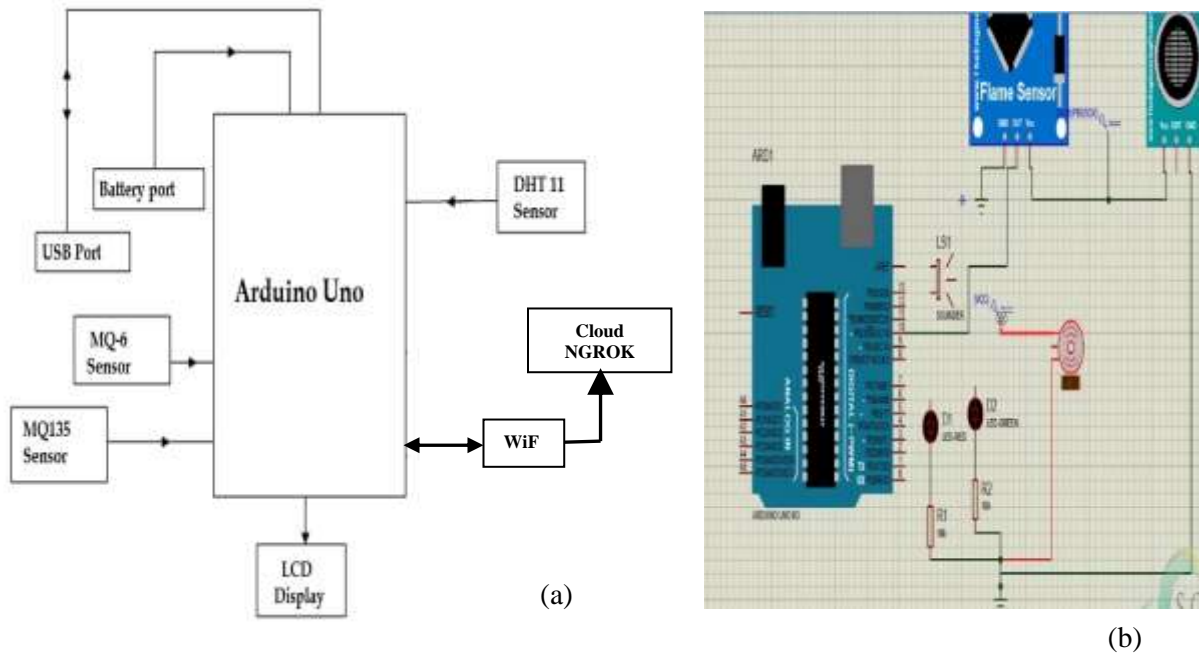


Figure 1: Air Quality Monitoring Device (a) block diagram (b) circuit diagram in Proteus 8

The method and approach of the design and implementation of the weather device is shown in Figure 2 which is the flowchart of the program used for the implementation. Embedded C++ computer programming language to was used program the Arduino Uno microcontroller to link all the core and peripheral hardware components. This was simulated in Proteus software. The Arduino Uno contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with an AC-to-DC adapter or battery to get started since it featured the Atmega8U2 programmed as a USB-to-serial converter. The Arduino software contains a serial monitor which allows import SQL data to be sent to and from the board the receiver and on the board will flash when data is being transmitted via the cheap and USB connection to the computer.

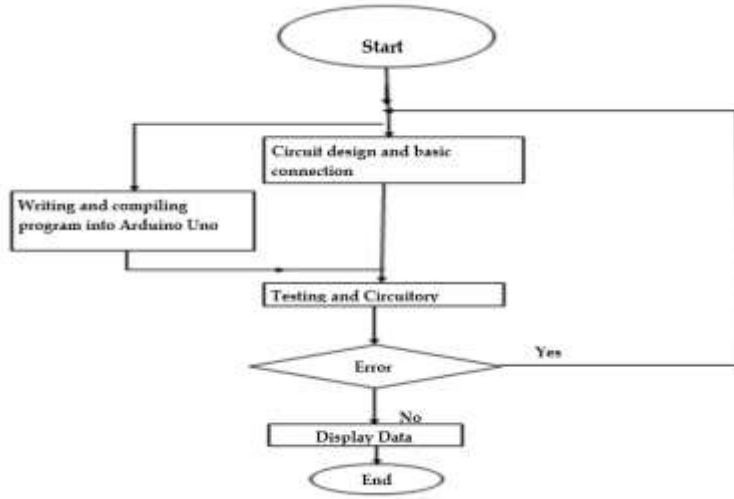


Figure 2: Flowchart of the Program for Implemented Air Quality Device

**Measurements of the Air quality and Meteorological Variables**

Measurements of air quality, temperature and humidity and atmospheric pressure were carried out for about 1 week between Monday 12<sup>th</sup> and Friday 16<sup>th</sup> July 2021. This air quality monitoring device monitored and displayed the measured air quality parameters and meteorological variables values to the Microcontroller. The microcontroller computes the monitored values and sends them to the data logger. Then the monitored variables are displayed on LCD and can as well be sent to the PC via a serial code.

Air quality measurements were first taken at Evbogida market, Egor, Edo state. Evbogida is located around Latitude 6.36° and Longitude 5.61°. The second measurements were taken at Oba-ile, Akure north, Ondo State. Oba is located around Latitude 7.24° and Longitude 5.23°. Both areas have a humid tropical climate with the latter in the savannah zone. Both locations are densely populated. The device measured air quality, temperature (°C) and relative humidity (%). The record covers 12 hours each day from 6:00 to 18:00 hour’s local time hourly. The daily averages are copied from the air quality display interface or the Ngrok web server. The air quality variables and the measured meteorological variables were analysed using appropriate statistical tools in Microsoft Excel. The detailed equations for calibration are described in (Mohammed, 2021).

The implemented weather monitoring device was working properly. For quality assurance and validation, measurements of air quality and other meteorological variables; temperature and relative humidity were carried out at Ebvogida, Egor in Edo state as presented in Figure 3.

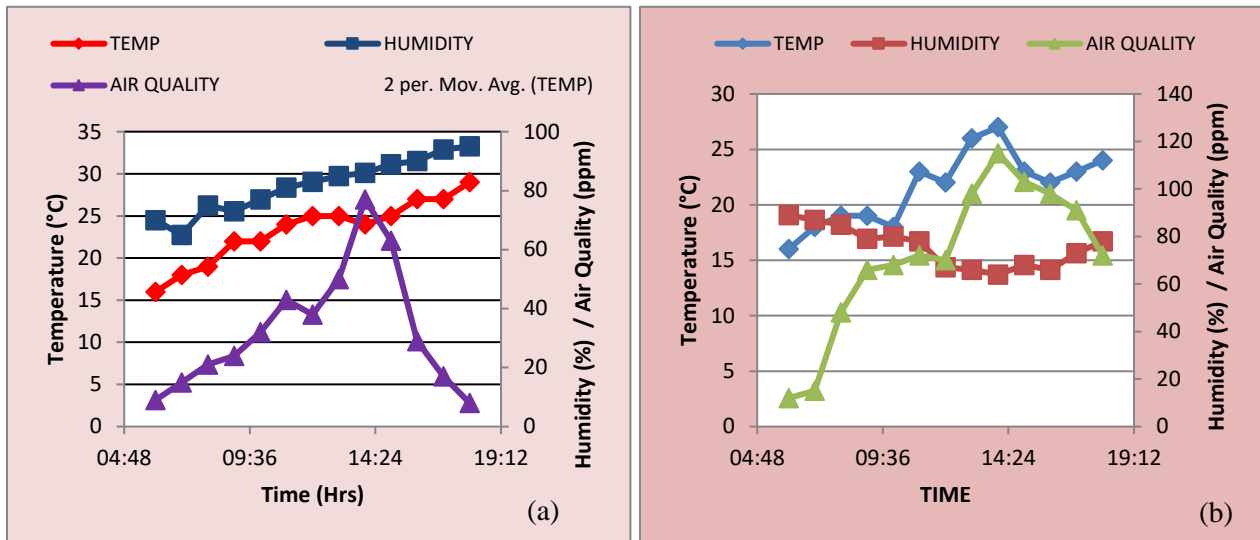


Figure 3: Graph of temperature, humidity and air quality against time for Evbogida market, Egor on (a) Monday 12<sup>th</sup> (b)Friday 16<sup>th</sup> July 2021.

The recorded measurement Oba-ile, Akure north in Ondo state are shown in Figure 4.

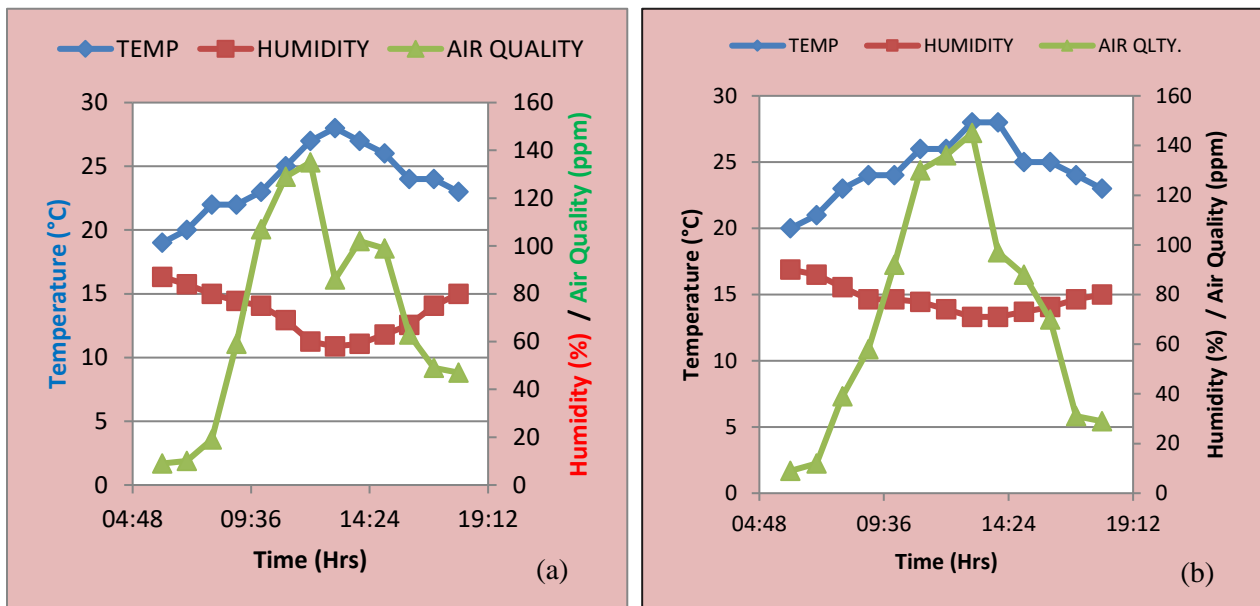


Figure 4: Graph of temperature, humidity and air quality against time for Oba-ile, Akure on (a) Monday 19<sup>th</sup> (b)Friday 23<sup>rd</sup> July 2021.

It's clearly shown that the air quality in Figures 3 and 4 is generally higher during the day from 8:00 to 16:00 at the two different locations. This is because both locations are highly populated with agglomeration of buildings where people live and work, so the pollution from moving vehicles causes the rise air quality. From the graph temperature varies inversely with humidity, this can be attributed to the fact that an increase in temperature will cause the water molecules in the atmosphere to warm up and evaporate faster thereby reducing the amount of water molecules per unit volume leading to a drop in humidity level.

**Testing and Output**

Before the code was uploaded to the Arduino uno microcontroller, a Wi-Fi was connected to ESP8266 device. After uploading, the serial monitor showed the IP address in Figure 5.



Figure 5: Offline results of the air quality parameters

An offline server was created to monitor the air quality parameters; the IP address of the device was entered in a browser to show you the output as shown in the Figure 6. The page will have to be refreshed again to see the current Air Quality Value in ppm.



Figure 6: Offline results of the air quality parameters

A local server was set up for demonstration. But to monitor the air quality from anywhere in the world, the port 80 (used for HTTP or internet) and the IP address was forwarded to a VPN (virtual private network). After port forwarding, all the incoming connections will be forwarded to this local address and anyone can access the webpage shown in Figure 7 by entering the public address on their browser from anywhere. The online air quality results will appear as presented in Figure 8.

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ngrok by @inconshreveable (Ctrl+C to quit)

Session Status      online
Account             Emmanuel (Plan: Free)
Update              update available (version 2.3.40, Ctrl-U to update)
Version             2.3.38
Region              United States (us)
Web Interface        http://127.0.0.1:4040
Forwarding           http://08cf8668796d.ngrok.io -> http://192.168.43.42:80
Forwarding           https://08cf8668796d.ngrok.io -> http://192.168.43.42:80

Connections
  ttl   opn   rt1   rt5   p50   p90
  248   5     0.30  0.26  21.00  21.01

HTTP Requests
    
```

Figure 7: NGROK VPN server showing web page address



Figure 8: Online results of Air Quality Parameters

**CONCLUSION**

The fundamental aim of this research project was to construct and implement an affordable, flexible and portable air quality monitoring device for the purpose of tracking and analysis of air quality and some meteorological variables like temperatures relative humidity. Indoor air quality can also be efficiently monitored by this device anywhere and in real time by using an Ngrok web server for security of the platform and the data. The system is able to monitor any pollutants using the MQ6 and MQ135 gas sensors to sense different types of dangerous gases. Arduino, which control the entire process is the heart of this project. Wi-Fi module connects the whole process to internet and LCD is used for the visual output.

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