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# LoRa Sensor Node Mounted on Drone for Monitoring Industrial Area Gas Pollution



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## HIGHLIGHTS

- Polluted gas concentration collected over industrial areas showed dangerous CO levels, highest at 9.75µg/m$^3$
- Data was collected at two sites above the industrial area over a 1.5km distance back and forth
- Sensor node payload deployed by drone with LoRa sx1278 communication between node and base station
- CO concentration among pollutants approached dangerous levels at site 1

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## ABSTRACT

One of the biggest threats to human health is air pollution, which significantly influences people. Due to challenges like industrial and rural locations, where sensing frequently falls short of providing sufficient information about air quality, it is challenging to collect data close to pollution sources. Government-led statically deployed stationary monitors are typically used for air quality monitoring. However, many emissions that contribute to air pollution are erratic and unpredictable. A significant problem for environmental protection will be how to monitor air pollution emissions dynamically and efficiently. It can fulfill two objectives. The first is that if the Unmanned Aerial Vehicle (UAV) is flying to a remotely monitored target, it can relay the detected data back to the server in real-time. This work aims to suggest an innovative mobile wireless air pollution monitoring system comprising UAVs with inexpensive air pollution sensors that transmit data over Long Range (LoRa). The outcomes also demonstrated that LoRa Radio transmitter sx1278 could transmit data for distances up to 5km in urban areas. The system was tested successfully at two sites in the Ewairij industrial area south of Baghdad, and the data was received at the base station from the sensor Node, which is carried by the drone during its flight for a distance of 1.5 km and height of 20 meters, round trip. As a result, the industrial areas were classified according to the Air Quality Index (AQI) between satisfactory to moderate according to gas concentrations. The highest gas carbon monoxide (CO) concentration increase was close to dangerous in both sites, as it recorded 9.75µg/m$^3$ in site#1 and 7.75µg/m$^3$ in site#2. In conclusion, the AQI did not reach a poor level in these tested areas.

## 1. Introduction

The continual alterations in ambient air brought on by anthropogenic and natural emissions (like gaseous pollutants or aerosols) substantially impact air quality and human health [1]. One of the top 10 dangers to human health, according to recent studies on the "Global Burden of Disease," is air pollution. According to estimates, air pollution causes 7 million premature deaths annually, making it the world's most significant environmental hazard to public health [2]. Chronic respiratory disorders, lung cancer, heart disease, and strokes are brought on by air pollution [3,4]. Several early fatalities have been directly linked to air pollution since many cities routinely breach the acceptable concentration ranges of air contaminants [5].

However, to assess air quality, mostly employ a specialized gas sensor for CO detection, flammable gas, toxic gases Sulfur dioxide ($SO_2$), or ammonia ($NH_3$). All air quality circumstances should be included throughout the examination [6]. According to a study that examined the risk factors for chronic bronchitis among residents of highly polluted locations, individuals who live close to a mining or industrialized area have a 35% higher risk of developing a chronic cough with sputum than those who have a risk of only 18% [7,8].

Pollution has severely impacted the quality of life in any surrounding residential dwelling in some places of the world due to extensive industrial activity or the impact that specific practices used in quarries, mills, or processing plants have on the nearby



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environment [9,10]. High pollution concentrations from oil-burning plants, which power highly industrialized economies but harm the health of those who live nearby, are another element that impacts air quality in the city [11,12]. Environmental pollution and the emission of hazardous gases occur in the areas south of Baghdad in the Ewairij industrial zone and the Dora refinery, where harmful gases are emitted from oil refining. Likewise, in factories for plastic and foods, the electric power plant relies on burning gases to generate energy, resulting in much smoke from this combustion process [13].

Higher spatial and temporal resolutions are possible with low-cost sensors, which alter how air pollutants are typically measured. However, because the sensor surface directly interacts with a tiny volume of chemical substances, the low-cost sensors' detection range is significantly smaller than that of conventional observing tools [14]. Hence, from an economical and deployment-related standpoint, a fixed sensor network is inappropriate in most situations [15-17]. In addition to the limitations in the transmission and receiving distances of wireless networks such as Wi-Fi, Bluetooth, and Zigbee, it makes it difficult to transfer data and cover vast distances, such as LoRa and Wireless Protocol [18].

UAV technology has become increasingly popular, and scientific and non-scientific databases have amassed substantial data regarding air pollution [19-21]. It is crucial to many other areas, including food security, which helps fight food insecurity brought on by the COVID-19 epidemic. UAVs present fresh difficulties regarding payload capacity, power consumption, and stability [22]. Moreover, the selection of sensors is restricted since they must be acceptable and small enough to be mounted on UAVs. This could result in choosing sensors with lower sensitivity and selectivity [23]. LoRa-modulated transmission is immune to interruptions and can be received across considerable distances. LoRa is ideal for applications that send small amounts of data at slow bit rates. Data can be transferred farther than it can with ZigBee, Bluetooth, or WiFi technologies [24, 25].

Instead, better spatial coverage is achieved by installing wireless sensors in public vehicles like trains, trams, and buses to measure air quality [26]. Nevertheless, the areas such vehicles go through limit the sensory readings [27]. In order to solve the patchy coverage, there has been a clear shift toward using strength in numbers to produce high-resolution air quality data.

Nevertheless, current initiatives only focus on examining the advantages for particular populations and proving that crowdsourcing data is feasible [28-33]. Technology developments have reduced the cost of detecting gaseous contaminants. This enables the creation of novel techniques for determining the concentrations of various substances utilizing portable equipment that is mainly made. They provide a new method of identifying low air quality conditions and can be used to capture many air quality data streams for research [34]. In work by Kersnovski et al. [11], a microcontroller-based toxic gas detector detected and alerted to harmful gases, including Liquid Petroleum Gas (LPG) and propane emissions. When the safety level for these gases is exceeded, an alert is created, and an authorized person receives an SMS message via the GSM modem. The PIC 16F877 microcontroller and the MQ-2 and MQ-6 gas sensors build up their system. Rossi and Brunelli [35] created a Wireless Sensors Network (WSN) for monitoring air pollution outdoors. The developed model was evaluated in real-time. The sensors record Ozone ($O_3$), Nitrogen dioxide ($NO_2$), CO, and Hydrogen sulfide ($H_2S$) pollution data, and the sensed information is sent to the server through General Packet Radio Services (GPRS).

Regarding measuring gas contaminants that are evaluated by Malaysian ambient air quality guidelines, another study [36] created the low-cost Dirac Sense air quality system. They used sensors made by Alpha sense, including CO-AF, OX-AF, and $NO_2$-AF. Electrochemical sensors measure gases such as CO, $O_3$, and $NO_2$. The PTU300 sensor detects relative humidity, pressure, and temperature. The work by Glass et al. [30] offered an air pollution and monitoring model that includes Metal Oxide Sensors (MOS) types MQ-5 and MQ-7 sensors, which is actually as a server to store all the collected data, and a Bluetooth microcontroller for transmitting sensor values from an Analog-to-digital conversion (ADC) to the server. They also provided the Iterative Dichotomiser 3 method, which uses probability to determine sensor values kept on the server. A CO and Hydrogen ($H_2$) measurement and forecasting system for air pollution was created by Johnston et al., [37]. Their solution includes a Beagle Bone Black microcontroller, MOS (MQ-7, MQ-11) sensors, and a Global Positioning System (GPS) module to monitor the pollution level. Python Structured Query Language (SQL) is used to upload the sensor data onto Azure Cloud. A real-time WSN-based pollution monitoring system for ground mobile objects was presented by Rautela [38].

The sensors detect CO, Carbon dioxide ($CO_2$), and $O_2$ gas concentrations when placed on calibrated sensor nodes. The project was carried out in Hyderabad's industrial zone. Ding et al., [39] created an Air-sense system for monitoring indoor and outdoor air quality. Their AQMD (Air Quality Management District) comprises an Arduino Pro Mini board as a microcontroller, MOS (MQ-7, MQ-135) for CO detection and air quality monitoring, and Bluetooth module HC-05 for sending data from the AQMD to mobile devices. Wehler et al., [40] presented a low-cost vehicle sensor network-based air quality monitoring system. This system analyzes the information gathered by sensors mounted on public vehicles.

Chen Proposed [41] a low-cost portable system for air pollution monitoring utilizing (Internet of Things) to educate the public about the air quality and empower them to make better decisions about their travel plans or home purchases in a better location. Researchers have been experimenting with mobile flying objects like UAVs to help mobile-ground systems overcome their limitations in terms of limited spatial resolution.

Moreover, it has been demonstrated that air pollution varies abruptly vertically and horizontally, even at a tiny relative distance [42]. Zorbas et al. [43] suggested an Air Pollutants Monitoring Using UAVs project for flying mobile devices to determine a toll to assess air quality vertically at various altitudes. Haiahem et al., [24] proposed using the AIRWISE airborne WSN system to measure and track environmental air pollution continuously. In order to make monitoring of air contaminants easier, the author of [44] proposes a data-collecting system and how it can be coupled with a UAV. For processing, the ground station receives the collected data through RF transmission.

This work suggests a new UAV-based real-time air quality monitoring system to explore the levels of air pollution in broad industrial areas. This technique focuses on the distribution of gaseous concentration with altitude. Furthermore, by creating a detection system based on inexpensive sensors and a cost-effective and open-source UAV, it is efficient to construct a mobile-wireless air pollution system to measure gas concentration, such as CO, LPG, $SO_2$, $NO_2$, $NH_3$, and smoke. LoRa Wireless

Communication protocol is used to overcome the limited range of communications, sending and receiving data over long distances of up to 5 km in urban areas and up to 18 km in open areas [28, 29]. Therefore, this technology is used with drones to secure access to hard-to-reach areas, especially in the presence of polluting and toxic gases. Following are the contributions made by this article's work:

1) It displays a productive longitudinal real-world installation of inexpensive mobile air quality sensors in the Ewairij industrial area.
2) It illustrated the effectiveness of our campaign by using sensor data to cover the entire area in high resolution and recording these values.
3) It offers insightful information about the local air pollutants and credible explanations about their occurrence and solutions for reducing them.

Our system can provide citizens with individualized data on their exposure to air contaminants during regular commutes. The remainder of this paper is organized as follows: The second section reviewed Materials and Methods, comprehensively describing the suggested sensing system and thoroughly examining its key components. The analysis of the data acquired during the system evaluation is the emphasis of the third section. The results and discussion are presented in the fourth section. Finally, the conclusions of the article are summarized in the fifth section.

## 2. Materials and Methods

The practical test was conducted in the Ewairij industrial area, south of Baghdad, where a sensor connected to a microcontroller collected information about polluted gases. Then, the data was sent via LoRa to the base station, all mounted on a drone. The drone flight to detect polluted gases lasted for a distance of 1.5 km, back and forth. The sensors were calibrated through a specific program for each sensor. Before that, each sensor was heated for 48 hours. The test was conducted in the second month of 2023 in a partially sunny atmosphere.

### 2.1. System Model

The UAV sensor node, base station, and laptop were used for the air monitoring system. The sensor node wirelessly relayed the encrypted data to the base station while continuously monitoring the air quality parameters, as shown in Figure 1. The data was subsequently transferred from the base station to the laptop for immediate data processing, visualization, and storage. This system's data flow was unidirectional, always going from the sensor node to the laptop. However, the sensor node may be remotely controlled from the laptop with a slight change to the system code. The data uploaded from the MQ gas sensors is collected in the Arduino Nano, which transmits to the LoRa transmitter to send the data to the base station at a frequency of 433 MHz. At the base station, the LoRa receiver collects the data and sends it to the Arduino Uno, which in turn processes and transmits it to the laptop to store and monitor the data. Three main systems comprise the sensor node: MQ gas sensors, wireless communication, and management power, as shown in Figure 1 and Figure 2.

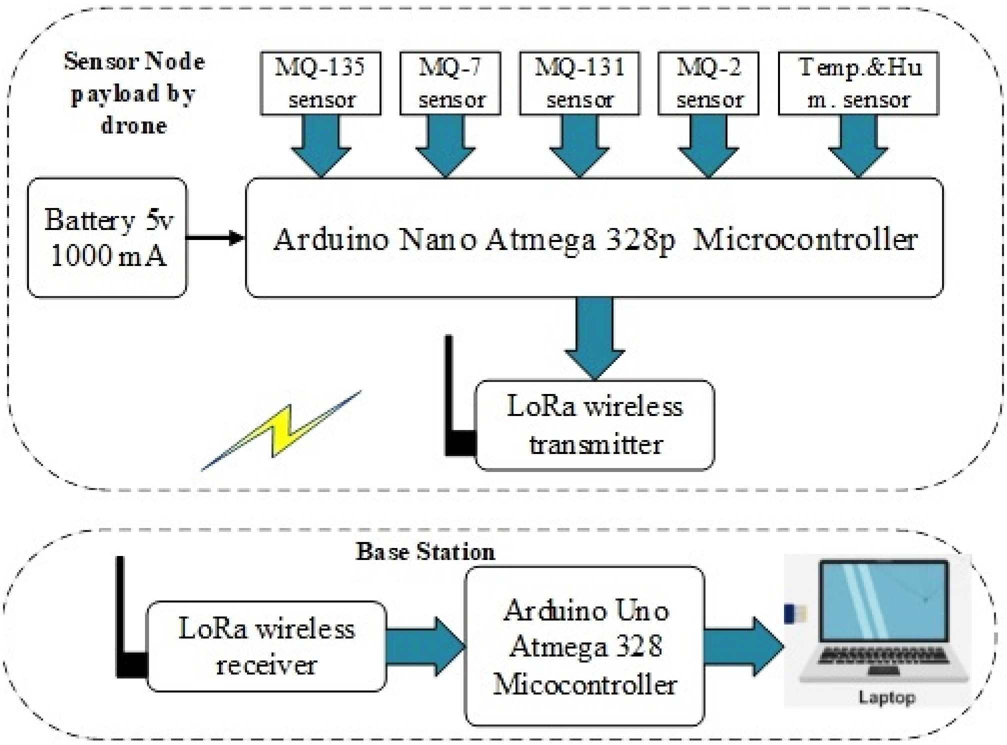


**Figure 1:** Air monitoring system based on UAV schematic diagram

The temperature, humidity DHT11, MQ-2, MQ-131, MQ-7, and MQ-135 sensors and the circuitry required to power them are all included in the sensor node module. MQ-2 is used to detect (smoke, LPG, $H_2$, and Propane) while MQ-131 is used to detect $NO_2$, $SO_2$, MQ-7 for CO and MQ-135 for $NH_3$. The gas sensors must be calibrated according to the manufacturer's specifications; their values depend on the temperature and humidity of the surrounding air. Quadcopter UAV types Holy Stone HS 700D are used in this system to the payload sensor node. This system used LoRa SX1278, a radio for data transmission over long distances, and an Arduino Nano as a microcontroller for data reception and storage. The power management module's custom-built circuitry recharges the rechargeable Li-ion battery 5v 3000 mAh that powers all the electronics in the node. Sensor node components are shown in Figure 2a. Sensor node mounted on drone illustrated in Figure 2b while Figure 2 c and Figure 2d explain drone in duty and the base station respectively.

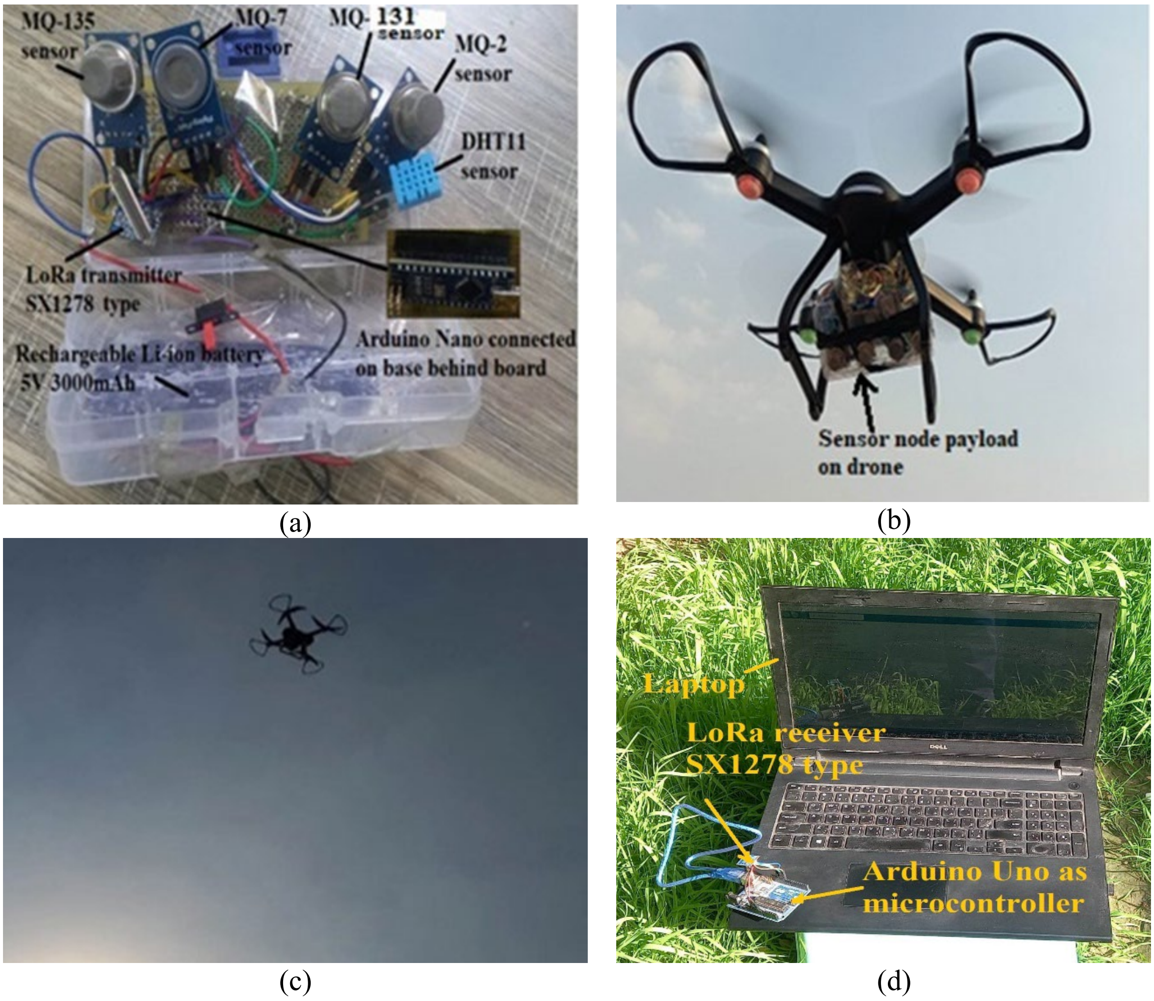


**Figure 2:** Hardware for the proposed system including (a) Sensor node of an air monitoring system including 4 MQ gas sensors, (b) Sensor Node payload with a drone, (c) Drone on service to detect polluted gases, and (d) Base station of the monitoring system

## 2.2 Algorithm of Transmission and Receiving Data

An algorithm sends and receives data between the sensor node and the base station. The LoRa sx1278 in the sensor node allows data to be transmitted from the MQ sensors to the base station. The battery 4V 1000 mAh unit's power source supplies enough power for the Arduino Nano ATmega 328p and wireless LoRa sx 1278 -dependent data transmitter unit. The battery is rechargeable and placed on voltage regulators of 5V and 3.3V for providing power to Arduino Nano AT mega 328p and wireless LoRa, respectively. The acquisition system, built on the ATmega 328 microprocessor, gathered data from the MQ sensors. The ATmega 328p microcontroller determines the real-time gas concentration values received from MQ-polluted gas sensors. Additionally, the findings can be shown on the laptop in the monitoring unit using the LoRa receiver and the Arduino UNO at a base station.

The LoRa wireless module received the polluted gas data from the data transmission module. The wireless LoRa at the transmitter and receiver operate at a frequency of 433 MHz. The sensor node and base station can be communicated using two LoRa modules without additional hardware or protocol conversion. LoRa wireless may be accessed via the serial peripheral interface of any microcontroller, making it simple to access for customizing the output power, air data rate, and channel frequency. For clarity, the transmitter and receiver code flow diagram used in this paper is shown in Figure 3 (a and b).

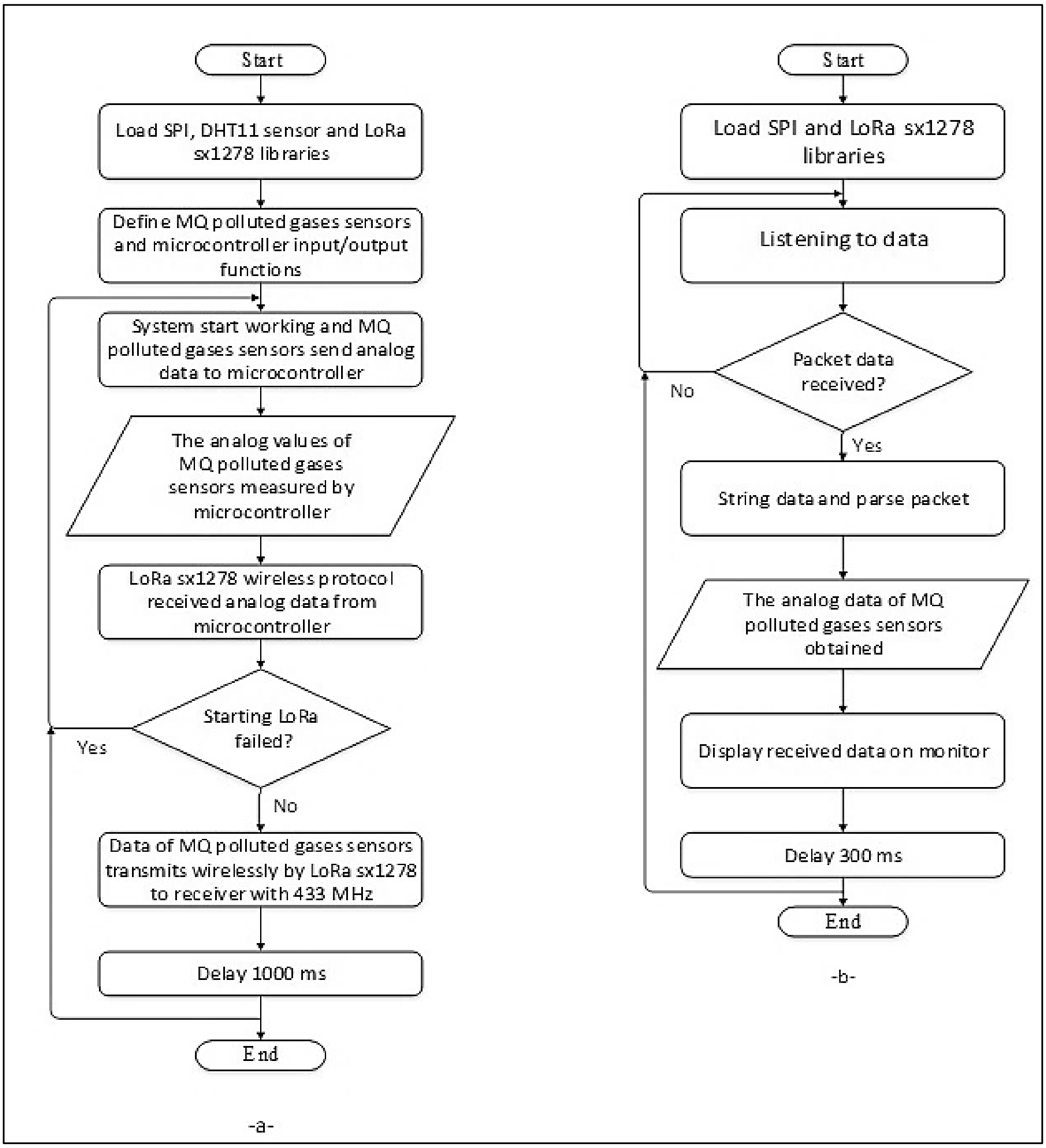


**Figure 3:** Data transmission coding flow chart of the proposed system using LoRa wireless protocol (a) Sensor node transmitter code (b) Receiver code

## 2.3. Gas Concentration Measurement

It is necessary to measure the concentrations of polluting gases, and this is done by using many sensor types, most of which are specialized in a specific type of polluted gases, including low-cost sensors. However, they need to be calibrated because their readings are inaccurate, so they need to be adjusted before inserting them into the airspace to give the actual values of the gases contaminated. These sensors are MQ-2, MQ-131, MQ-7& MQ-135 [7]. Gas Sensors are manufactured to sense or measure the following gases: $SO_2$, smoke, $NH_4$, $NO_2$, CO, $H_2$, Propane, Alcohol, and LPG. Methods for measuring Gases: Several complex methods must be used to measure a specific gas or a group of gases. To calculate the ppm of a gas concentration. The steps below have been followed.

Graph analysis for the MQ gas sensor [5] shows that the sensitivity characteristics to several gas curves are formed using two parameters. As a function of the Rs/Ro value, the concentration of various gases is expressed in ppm. Rs represents the sensor's resistance at various gas concentrations, and Ro at 1000ppm of gas in clean air. By calculating the gas's Rs/Ro ratio, we may compare it to the comparable gas curve. There are two steps in it; the first is figuring out Ro, or the resistance of the air around. Ro as expressed in Equation 1 [5] is calculated by dividing the gas resistance in the surrounding air, Rs, by the resistance in clear air, Ro, which for the MQ-2 gas sensor is 10k Ω:

$$\text{Ro} = \frac{\text{surrounding air gas resistance Rs}}{\text{clear air resistance of Ro}} \quad (1)$$

The following Equation 2 using to determine Rs [5]:

$$\mathrm{Rs} = \left(\frac{\mathrm{V_c}}{\mathrm{V_{RL}}} - 1\right) \times \mathrm{R_L} \tag{2}$$

where vc is the voltage supply to the sensor, which is equal to $(5v \pm 0.1v)$ and $V_{RL}$ is the voltage across RL resistance.

Eventually, the ratio Rs/Ro is calculated. It describes the sensor's response at various gas concentrations. An equation can be generated from the sensitivity characteristics of each gas curve by noting down various points. This power regression can analyze the relationship between Rs/Ro and ppm variables. The Arduino was configured to receive the signal from the gas sensors and generate a voltage proportional to the gas concentration. Then, transform this voltage into sensor resistance Rs. and determine the Rs/Ro ratio. The gas concentration in ppm can be determined by entering the Rs/Ro value into the equation derived from the trend line. The power function was discovered to provide the most excellent fit for the collected data after values from the sensitivity curve were extracted. The curve plotted for the above values is shown in Figure 4. The trend line displays the equation that most accurately captures the curve.

The equation derived from the trend line: y = -0.921ln(x) + 9.7124 where x is gas concentration in ppm and y is Rs/Ro. after rearranging the equation, obtain the gas concentration as expressed in Equation 3 [5]:

$$\text{Gas concentration (ppm)} = \left(0.05363\frac{\mathrm{R_S}}{\mathrm{R_O}}\right)^{-2.1834} \tag{3}$$

The sensitivity is generally the same for all the gases that the sensors can detect. Gas sensors need to be preheated for about 48 hours for best results. The value of $R^2$ about 0.9972, where R squared measures how well our data matches the regression model. It is the correlation coefficient's square (r). A regression prediction's R2 value of 1 means the data fits the prediction exactly. The equation's correlation coefficient, 0.9972, is exceptionally high. Better correlation is achieved by moving closer to the value 1. The exact process was used for all the MQ gas sensors, and power regression was implemented to extract the formula.

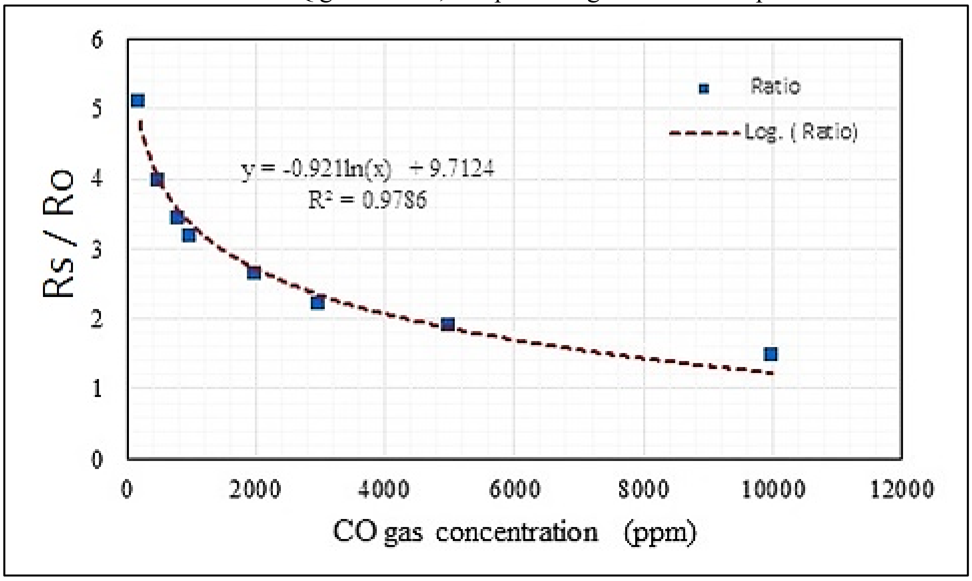


**Figure 4:** Trend line for CO gas concentration of MQ-2 gas sensor

## 3. Area Under Test

Field tests were implemented in February 2023 over the Ewairij industrial area south of Baghdad. This region produces a lot of polluted gases emitted from chemical laboratories and factories for various products, so it is considered a fertile environment for conducting investigations of polluted gases in this region. The collected data was done in industrial area locations along roughly 1.5 km. Figure 5 shows a Google Maps aerial view of the industrial area. Without attaching the sensor node to the UAV, the system underwent several rounds of testing on the ground. Both static (lab tests) and mobile (sensor node fly throughout the industrial area) testing were done. The ground station's and sensor node's circuits and codes must be tested to ensure they function correctly. The UAV was equipped with the sensor node, which was then tested in an open, industrial environment for two sites (site #1 and site #2). The drone flight in each site is about 3km. Figure 5 shows the path of the drone route used to measure polluting gases over the Ewairij industrial area, south of Baghdad, with the help of Google Map distance, meaning 1.5 Km round and back, with a period of 10 minutes. The test was done in February 2023 on a partly sunny and breezy day.

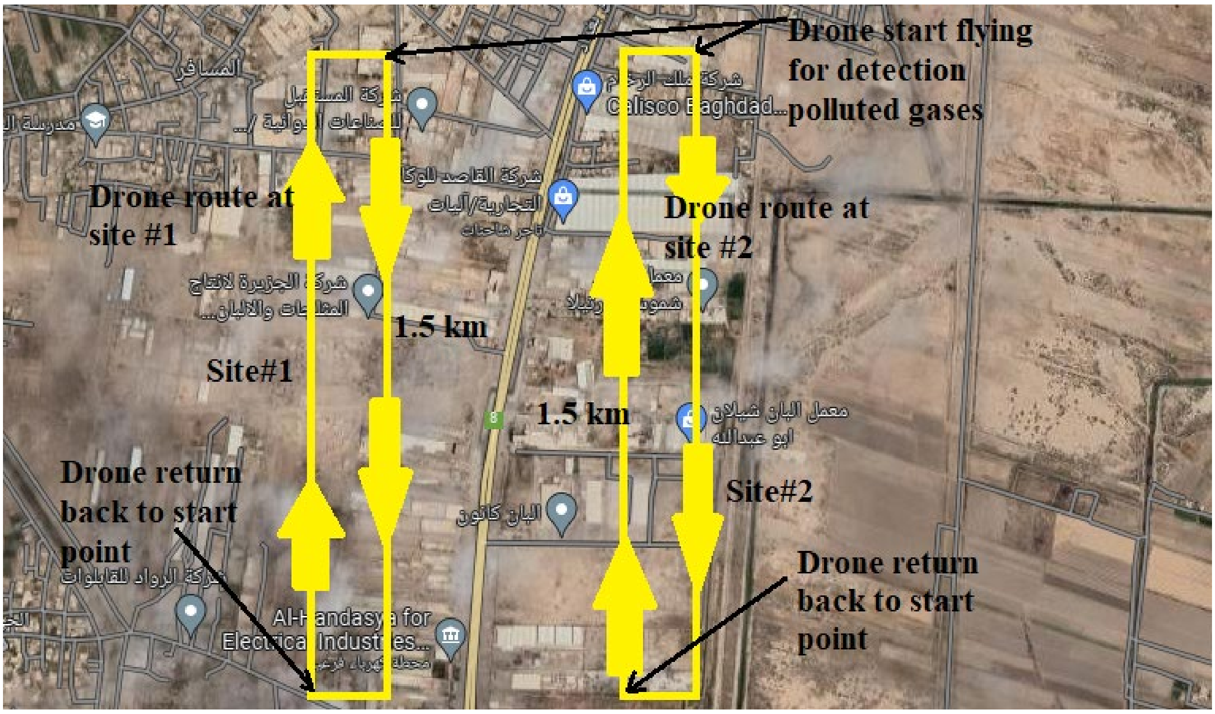


**Figure 5:** An image showing the path taken by the drone to measure the concentrations of polluting gases over the Ewairij industrial area south of Baghdad with the help of Google Maps services

## 4. Results and Discussion

Gathering information in various locations around a large Ewairij industrial area covers a large area. Through the drone journey, which is the payload sensors node, it travels a distance of 1.5km back and forth in both sites, site #1 and site #2, with a period of 10 minutes in each site. Data were collected for six types of polluting gases: $NO_2$, $SO_2$, $NH_3$, CO, LPG, and smoke. The concentrations of these gases differed in each part of the site due to the variation in the area in terms of the presence of an electric generation station, the presence of cement and plastic factories and the like, and the presence of empty areas. The data received at the base station represent polluted gas concentrations in ppm, as shown in Figure 6 and 7.

Then, the data collected at the base station was converted from ppm to µg/m$^3$ using Equation 4 [7] to make data values suitable for comparison with National AQI standard gas pollution concentration values.

$$Concentration\ (\mu g/m^3) = \text{molecular weight} \times \text{concentration (ppb)}/24.45 \qquad (4)$$

The pollutant with the maximum Ik value obtains a reported AQI, as formatted in Equation 5 [7]:

$$I_k = \mathrm{I_{Lo}} + \frac{(1-\mathrm{BP_{Lo}}/\mathrm{C_p})\,(\mathrm{I_{Hi}}-\mathrm{I_{Lo}})\,.\mathrm{C_p}}{(1-\mathrm{BP_{Lo}}/\mathrm{BP_{Hi}})\,.\,\mathrm{BP_{Hi}}} \qquad (5)$$

where $I_k$ is the pollutant p index, the AQI value corresponding to $BP_{Lo}$ is $I_{Lo}$. $I_{Hi}$ corresponds to $BP_{Hi}$ in terms of AQI value.

The concentration breakpoint at or below $C_p$ is known as $BP_{Lo}$. The concentration breakpoint equal to or higher than $C_p$ is known as $BP_{Hi}$. The most excellent $I_k$ for each pollutant is given as the air quality index (AQI), with the index being normalized to the nearest integer. Figure 8 represents the values of polluted gas concentrations in µg/m$^3$ at site #1. In contrast, Figure 9 represents the polluted gas concentration at site #2 in µg/m$^3$ converted from ppm received from sensor node payload by drone. AQI released by board control of central pollution and Government agencies has used an AQI to track air pollution. As the AQI rises, there are more threats to public health.

Several nations each establish their air quality metrics based on the mean air quality over time. AQI is scaled in the range (of 0-500) and classified into six evocative categories ranging between (good to severe) [44,45] as shown in Table 1.

Table 1 compares the standard values based on which the AQI is divided into six categories and the values of pollutant gas concentrations obtained in site#1 and site#2. The outcome showed that the data was limited to only three categories, ranging between good, satisfactory, and moderate.

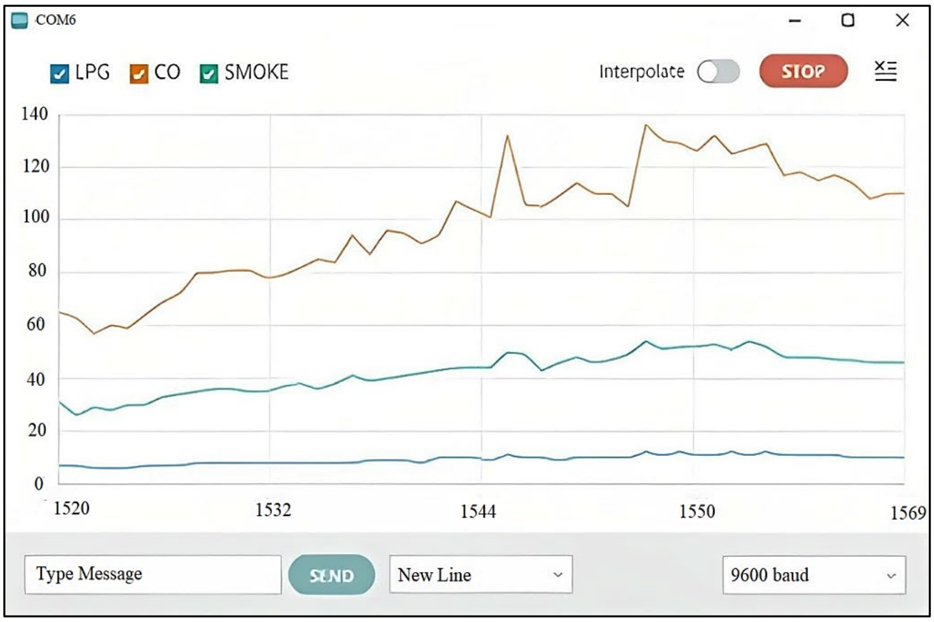


**Figure 6:** Part of data received at the base station for LPG, CO, and smoke in ppm

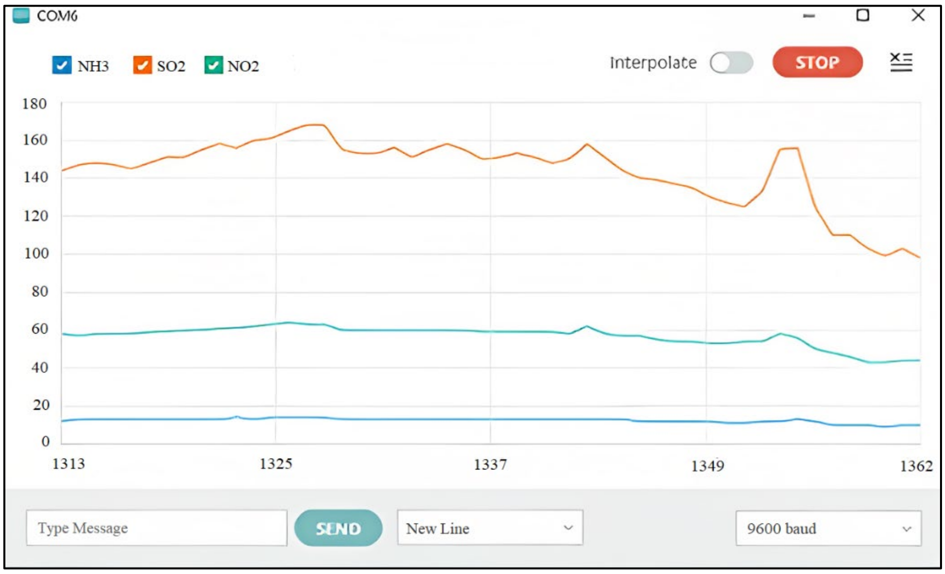


**Figure 7:** Part of data received at the base station for $NO_2$, $SO_2$, and $NH_3$ in ppm

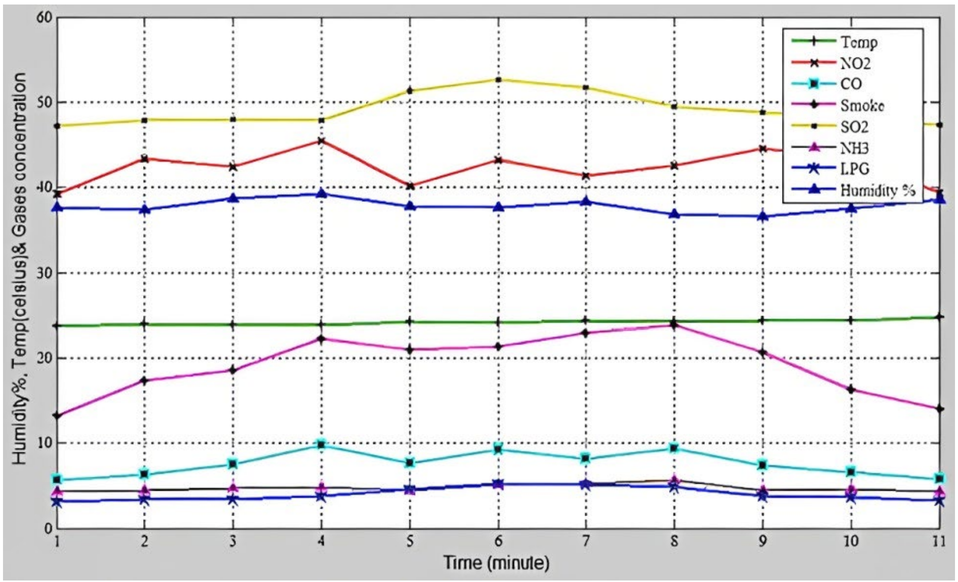


**Figure 8:** Pollution gases concentration at site #1 in µg/m$^3$

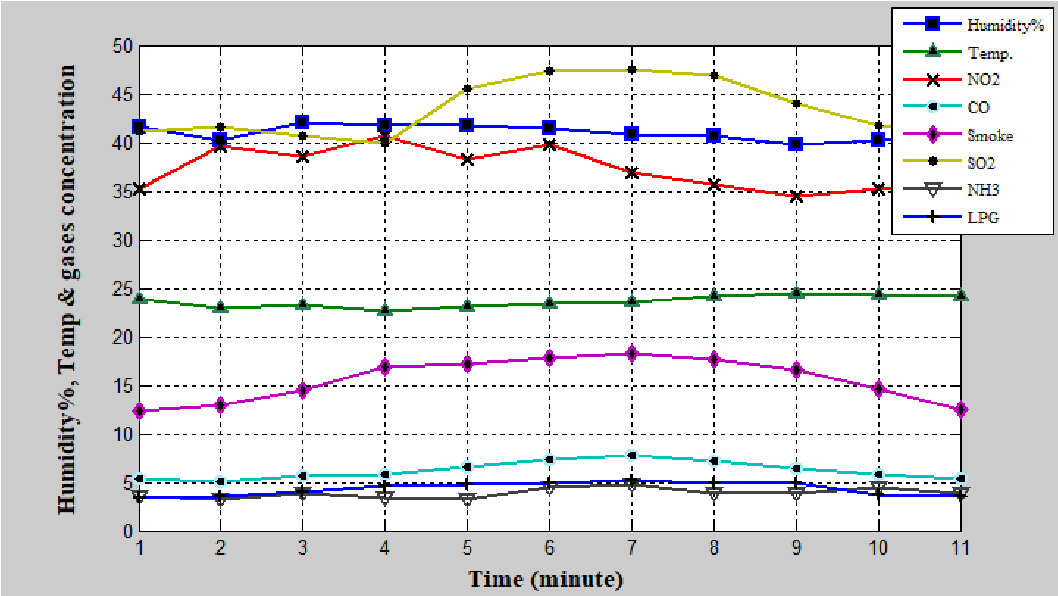


**Figure 9:** Pollution gases concentration at site #2 in µg/m$^3$

**Table 1:** AQI standard classifications [44,45] and gases concentration unit in µg/m$^3$ collected at site#1, site#2

| **AQI Category (Range)** | | **Good (0-50)** | **Satisfactory (51-100)** | **Moderate (101 -200)** | **Poor (201-300)** | **Very Poor (301-400)** | **Severe (401-500)** |
|---|---|---|---|---|---|---|---|
| | Standard | 0-40 | 41-80 | 81-180 | 181-280 | 281-400 | +400 |
| Nox | Site#1 | 39.24 | 40.21- 44.78 | - | - | - | - |
| | Site#2 | 34.46-39.7 | 40.66 | - | - | - | - |
| CO | Standard | 0-1 | 1.1-2 | 2.1-10 | 10.1-17 | 17.1-34 | +34 |
| (mg/m$^3$) | Site#1 | - | - | 5.68-9.72 | - | - | - |
| | Site#2 | - | - | 5.15-7.77 | - | - | - |
| | Standard | 0-40 | 41-80 | 81-380 | 381-800 | 801-1600 | +1600 |
| $SO_2$ | Site#1 | - | 47.23-52.61 | - | - | - | - |
| | Site#2 | 39.92-40.8 | 41.21-47.57 | - | - | - | - |
| | Standard | 0-200 | 201-400 | 401-800 | 801-1200 | 1201-1800 | +1800 |
| $NH_3$ | Site#1 | 4.32-5.64 | - | - | - | - | - |
| | Site#2 | 3.21 - 4.75 | - | - | - | - | - |

As a result, the standard air quality in the Ewairij industrial area south of Baghdad (the research region) varies between "satisfactory" and "moderately polluted" according to data sampling taken on 25th February 2023. The sensors on the drone collected data at a height of 20 meters, which is done by using decision tree classification. Data were collected in two locations in this industrial area, site #1 and site #2. The percentage of polluting gases in site #1 was more than in site #2 due to more laboratories and factories in site #1 than in site #2. The yellow color "satisfactory polluted" is almost concentrated in the open spaces, while the orange color "moderately polluted" is concentrated in the areas where there are power stations, cement, plastic, food factories, and the like, due to the emission of CO gas and smoke in large quantities as shown in Figure 10 that polluted areas are depending on AQI category in table1 and mentioned on google map.

The ability to discriminate against rotor flow influences at the measuring spot must be maximized to provide accurate measurement. In order to collect a sample of gas in the zone, this includes inserting a sensor, measuring equipment, or simply an air intake. At the same time, the drone's stability must be guaranteed throughout both hovering and flight. Identification of the zones with minimal rotor flow impacts near the drone body was the subject of extensive study. The bottom of the UAV body [11,34,35], its top [20,12], and its sides, mainly at the front [3,20], were taken into consideration as suitable positions for sensors, sensor devices, and air intake. To solve the issue of the drone disrupting the pollutant concentration field at the measurement location and guaranteeing an accurate measurement, the demonstrated sensing drone with the dropped and lifted multi-sensor measuring platform was created.

The measurement equipment seems to fit best directly under or on top of the drone's body for construction considerations, especially the ability to guarantee drone stabilization. Compared to rotor locations, bottom and frontal sensors fixed at the highest part of the drone showed the least sensitivity, as demonstrated in [36]. The lack of upward airflow caused by rotor movement and the resulting limited pollutant transport from the area surrounding the drone to this specific sensor exposure point was linked to the low sensitivity in the upper position. The rotor flow effect has little or no impact on the area above the drone corps. Due to this feature, applications focused on creating vertical profiles of different air characteristics in the environment frequently use the sensor's top placement. The measurement must be carried out on an upward flight path while ascending to ensure reliability. Compared to ground truth benchmarks for PM2.5, temperature, and humidity, employing the measurement system placed on the highest part of the drone shows promise, according to [30] measurements carried out in an upward flight path.

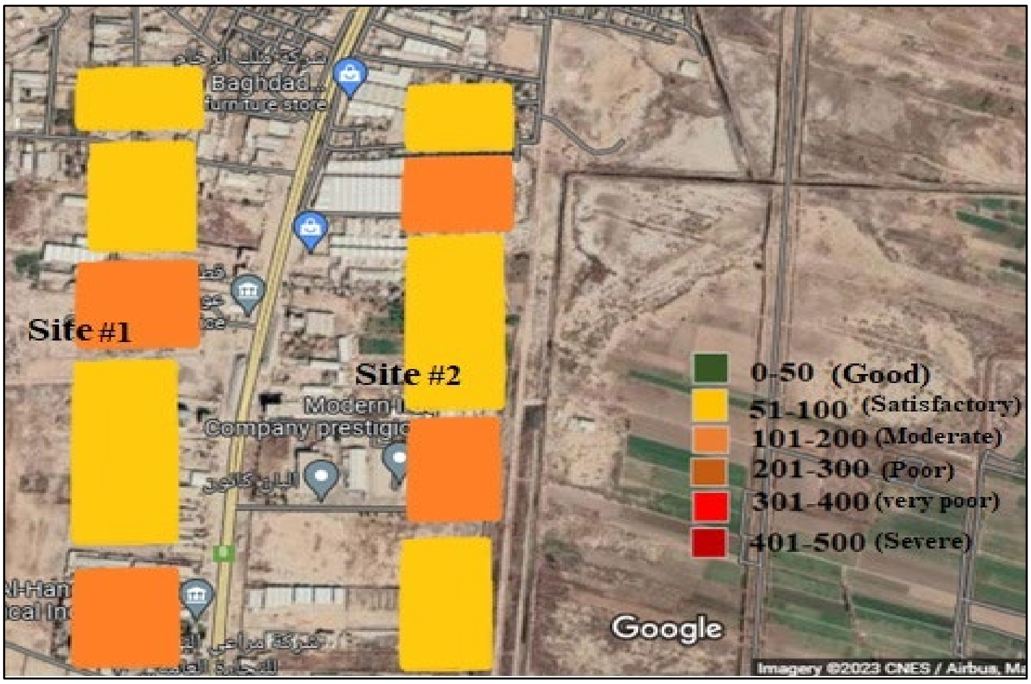


**Figure 10:** Polluted areas plotted depending on the AQI category in Table 1 and mentioned on Google Maps

The requirement for vertical rising flight is a significant restriction in environmental applications meant to determine pollution in different places and situations. It was demonstrated in [37] that sampling the air on the drone's bottom could not successfully detect Volatile Organic Compounds (VOCs) despite the measuring device's location. The downward wind drawn by revolving propellers was blamed for the failed extraction of VOCs. Significant amounts of p-xylene, benzene, and toluene were found using a telescopic shaft to expand the sampling range past the powerful downward stream that passes across the propellers. Both [17] based on measurements and [18] based on simulations, reported studies about air concentration drop under the drone. The downwash impact was thoroughly investigated in [34,38] utilizing simulation. It was demonstrated that the airflow always entered the rotor zone from above and left from below, independent of hovering height. It was additionally possible to identify the alleged ground influence. Specifically, a turbulence zone was created when the down flow returned back from the ground. It was demonstrated that the amount of space the turbulence took up decreased as the hovering height rose. The flow field descended without turbulence when the hovering altitude was limitless, and the current speed fell to zero.

The operating flying altitude determined suitable for the drone employed in [39] was 3m. The projects built under the presumption that the measurement tool was permanently linked to the drone and nearby faced the issues above. Our design was predicated on them occasionally shifting where they were in relation to one another.

We specifically suggested that the equipment should be attached to the drone during transit and that their separation should be as wide as possible during measurement. We specifically suggested that the equipment should be attached to the drone during transit and that their separation should be as wide as possible during measurement.

The outcomes reported in [6, 8-10, 40] support developing our monitoring drone with the dropped and elevated measuring platform. The devised method allowed measurements to be made numerous meters away from the drone hovering above the measurement spot. Furthermore, the ground effect could be avoided while measuring near the ground. The turbulence produced by the sensing device's lowering, elevating, and possibly swing and rotation was minimal due to its small stature and lightweight. These benefits of our sensing drone's lowered and raised measurement platform were supported by field tests that concentrated on measuring air pollution from open burning. As a consequence of the descending airflow caused by the drone rotors, we saw during field tests that the suggested sensing drone lessened the influence of the pollutant concentration diminished at the measurement location. This effect was seen when the measurement was made by the measurement equipment placed right beneath the drone, which was quite near to the ground.

The intensity of sensor responses in this instance indicates that no pollution was found. As a consequence of data analysis, it was concluded across all findings that gas concentrations were often greater near gas flares, which are typically located in oil fields [33]. This outcome demonstrated the system's sensitivity, even at low concentrations, of the test substance. Numerous parallels between our findings and those of [36] study could be drawn, largely as a result of the use of a similar $NO_2$ sensor across the two projects. The research authors suggested that the low temperature could have brought on the sensor's uncertainty behavior. The monitoring accuracy may be compromised as a result of the low temperature they experienced in their field test.

The majority of oil field applications are appropriate for it. Similar experiments have demonstrated that projects using LoRa modulation can transmit data farther in situations when a longer range is necessary.

According to one study by [24]. LoRa can provide appropriate coverage for networks of up to 3km in a metropolitan region with several residential buildings. The study Chen et al., [41] also demonstrated that the data transfer rate must be decreased to compensate for the signal strength loss to get the greatest range. With this project, it wasn't an obstacle. The data string length must be decreased to ensure communication stability if the pilot must remain in one place while multiple places need to be evaluated concurrently.

Martinez-Caro and Cano [42] proposed that adjusting the LoRa radio frequency could lead to a greater range with a lower data loss. Transmissions might be carried to a receiver location at a distance of about 7 kilometers by increasing the amount of spreading to 256 chips/symbol [43]. Even though less bandwidth and a slower coding rate are required, the highest bitrate of only 3.1 kbps is considered feasible. Even so, this bitrate is sufficient for this kind of work. In practice, a typical UAV is unable to travel 7km. So, this is not taken into account for this project. Throughout the field tests, the system's limitations were rapidly made clear. The UAV air tracking device relied heavily on the weather for functioning and effectiveness. Severe weather, such as strong winds and snowfall, made the operation impossible to manage. The UAV's execution degrades at higher elevations and when it is loaded. Despite their drawbacks, UAV services are still an attractive choice to track air quality in inaccessible locations and are relatively affordable. The author indicates that various issues, including communication, avoidance of collision, and cooperation, need to be solved in a project of a similar nature carried out by Now [44].

The proposed system of the sensing drone may cause issues about drone stability, particularly when the measurement platform is lowered and when the drone remains in flight while the detecting module is still down, several meters under the drone. The drone maintained stability despite the sway, and the pilot maintained complete control. The measurement platform's modest weight did not greatly impact the drone's operation, and the flight was successfully stabilized by the Pixhawk system's gyroscope. The drone's stability was unaffected throughout the testing system measurement and its earlier predecessors, and no hazardous situations would have caused the drone to lose control. However, the system stabilizes the platform if there is a significant swinging movement or rotational. This may be done in no more than two minutes. The appropriate operation includes elevating the measuring platform, stabilizing it with the mooring system, and then dropping it to resume the desired measurement position.

## 5. Conclusion

UAVs may currently perform complex autonomous missions in various academic subjects, including surveillance or remote sensing in dangerous situations, on land, the ocean, or both. Researchers have recently concentrated on using UAVs to monitor air pollution. This study suggested a UAV-based air quality monitoring system that offers information on pollutant behavior that covers long distances. We developed a low-cost method for measuring pollution that may be used to create fine-grained Google Map representations for specific places and monitor pollution in vast areas and at high altitudes. A mobile, low-cost monitoring device is susceptible and very effective when measuring air pollution in an industrial area. LoRa Sx1278 wireless protocol implemented in this proposed system can send and receive data over a distance of about 5km. A quadcopter-type Holy Stone HS700D was used to payload low-cost air pollution MQ sensors and LoRa transmitters to send data over 1.5km. The MQ sensors detect polluted $SO_2$, $NO_2$, CO, LPG, $NH_3$ and smoke gasses. The number of places tested around the Ewairij industrial area produced data information profiles and fine-grained Google Maps that classify pollution in various regions based on the AQI category range between (good and severe). In order to determine when pollution exceeds the legal threshold for safeguarding human health, further research can enhance the proposed UAV-based pollution measurement system to more accurately predict the dispersion of gaseous contaminants in a vast area environment.

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### Author contributions

Conceptualization, M. Fadhil, S. Gharghan and T. Saeed; methodology, T. Saeed; software, M. Fadhil; validation, M. Fadhil, S. Gharghan and T. Saeed; formal analysis, T. Saeed and M. Fadhil; investigation, S. Gharghan and M. Fadhil; resources, M. Fadhil; data curation, M. Fadhil; writing—original draft preparation, T. Saeed and S. Gharghan; writing—review and editing, M. Fadhil; visualization, S. Gharghan and M. Fadhil; supervision, S. Gharghan ,M. Fadhil; project administration, M. Fadhil, S. Gharghan. All authors have read and agreed to the published version of the manuscript.

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### Data availability statement

The corresponding author provides the data that backs up the study's conclusions upon request.

### Conflicts of interest

There are no conflicts of interest, according to the authors.

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