

## Distribution of Air Pollution Based on Distance from Emission Sources

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### Article Info

#### Article history:

Received 2026-01-16

Revised 2026-02-18

Accepted 2026-02-20

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#### Keywords:

Air Quality

Distance to Pollutant Sources

Arduino Uno

DHT22 Sensor

MQ-2 Gas Sensor

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### ABSTRACT

This research developed a microcontroller-based air quality monitoring system to analyze the effect of distance on the spread of pollutants from waste burning smoke and motor vehicle emissions. The system uses an MQ-2 gas sensor to detect smoke concentration and a DHT22 sensor to measure temperature and humidity, controlled by an Arduino Uno with real-time data displayed on an I2C LCD. Measurements were taken at distances of 30 cm, 60 cm, 90 cm, and 120 cm in indoor and outdoor locations and at different times. The results show that distance significantly influences environmental parameters, with gas concentrations and temperature being highest at the closest distance, while humidity increases at further distances. This system effectively records changes in air quality at a low cost and is easy to operate, making it suitable for use as an early detection tool for air pollution at the community level.

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## 1. INTRODUCTION

Air quality plays a crucial role in maintaining human health and environmental sustainability. According to a World Health Organization (WHO) report, more than 4 million premature deaths occur annually due to long-term exposure to air pollutants, particularly fine particles that are invisible to the naked eye [1]. Air pollutants can originate from natural sources such as volcanic ash and forest fire smoke, as well as from anthropogenic sources such as motor vehicle exhaust and household waste burning [2]. These activities produce hazardous compounds such as carbon monoxide (CO), methane (CH<sub>4</sub>), and fine particles PM<sub>2.5</sub>, which pose a risk to respiratory health [3].

Variations in air pollutant concentrations are strongly influenced by distance from the emission source. Previous research has shown that pollutant concentrations are higher closer to the source [4]. However, the limited availability of affordable and easy-to-operate monitoring tools hinders the public from accessing direct, real-time air quality information.

One solution developed is the use of Arduino microcontroller sensors for environmental monitoring systems. A study by Khairyansyah et al. (2023) demonstrated that Arduino is effective for real-time gas detection with low cost and high flexibility [5]. The MQ2 sensor is capable of detecting smoke and combustible gases, while the DHT22 sensor provides accurate temperature and humidity data, thus supporting comprehensive air quality monitoring. A sensor is a device used to detect or respond to changes in the physical, chemical, or biological conditions of the surrounding environment and convert them into signals that can be measured or processed by electronic systems [6]. Sensors can be applied in various fields, including the environment [7, 8], food [9, 10], and aflatoxin detection [11, 12].

This study developed an Arduino Uno-based air quality monitoring system that integrates the MQ2 and DHT22 sensors. Data were collected at various distances from the pollution source, both indoors and outdoors, and in the morning and evening, to analyze the effect of distance on environmental parameters such as temperature, humidity, and smoke concentration.

The novelty of this study lies in the application of a spatial approach to air pollution detection using a simple, economical, and responsive device. The designed system not only functions as a monitoring tool, but also has the potential to be an early warning system for the community in facing exposure to air pollution, especially in areas with high emission levels.

## **2. METHOD**

This research was conducted at two locations: indoors and outdoors. Two types of air pollution sources were tested: smoke from burning waste and exhaust fumes from motor vehicles. Measurements were taken at four distances: 30 cm, 60 cm, 90 cm, and 120 cm from the pollution source. Data were collected at two different times of day, morning and evening, to observe differences in air quality based on time and environmental conditions.

The research refers to Kumar et. al. [13], at each measurement point (30 cm, 60 cm, 90 cm, and 120 cm), the device was activated and left for approximately two minutes to allow the sensor readings to stabilize. The MQ-2 and DHT22 sensors automatically displayed gas or smoke concentration, temperature, and humidity on the LCD screen. The displayed data was recorded manually. This process was repeated for each measurement point, location, and time. The sensor response was fast and consistent.

### **2.1 Materials**

In this study, an Arduino Uno microcontroller was used as the main component. The MQ-2 sensor was used to detect smoke and gas, while the DHT22 sensor was used to

measure temperature and humidity. A 16x2 I2C LCD module was used to display the sensor readings. Jumper cables, a breadboard, and other supporting components were also used. The device was programmed using the Arduino IDE software.

## 2.2 System Circuit

The system circuit was designed by connecting the Arduino Uno microcontroller to the MQ-2 and DHT22 sensors, as well as to the 16x2 I2C LCD module as the display medium. The MQ-2 sensor was used to detect the presence of smoke or gas from combustion processes and vehicle emissions. The DHT22 sensor was used simultaneously to measure ambient temperature and humidity. The entire circuit was assembled in a portable case for flexible use in various measurement locations. The readings were displayed in real time on the LCD screen.

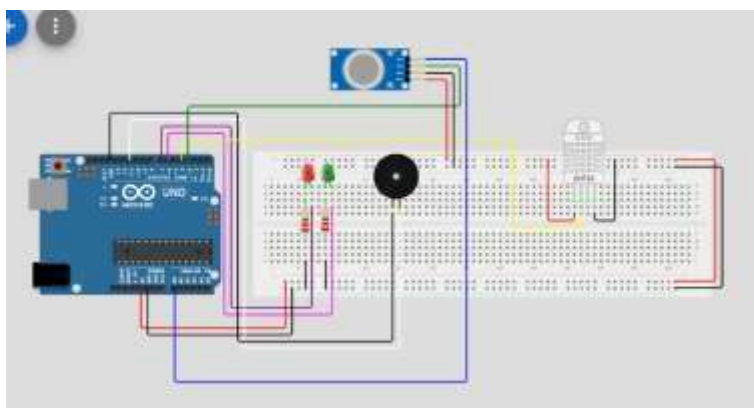


Figure 1. Component circuit in wokwi software

## 2.3 Data Analysis

The readings from the MQ-2 and DHT22 sensors were recorded in a table based on each measurement point. The analysis was conducted to determine the effect of distance on gas or smoke concentration, as well as changes in temperature and humidity. Comparisons were made based on two samples: smoke from burning waste at night and smoke from burning motor vehicles.

## 3. RESULTS AND DISCUSSION

### 3.1 Analysis of the Effect of Pollutant Source Distance on Pollutant Concentration, Temperature, and Humidity in Waste Combustion Smoke Samples

#### 3.1.1 General Analysis

This study aims to analyze the effect of pollutant source distance (smoke from waste combustion) on three environmental parameters: smoke concentration (read as a smoke index by the MQ2 sensor), temperature, and air humidity (read by the DHT22 sensor). Data were collected from six different treatments based on varying sensor distance from the smoke source: 30 cm, 60 cm, 90 cm, 120 cm, and 150 cm, as well as a sample-free treatment located farther from the pollutant source. The measurement results show a

fairly consistent pattern, where increasing distance is generally accompanied by a decrease in smoke concentration, a slight decrease in temperature, and fluctuations in humidity [14-16].

The MQ2 sensor outputs an ADC value that can be converted to gas concentration units (ppm) based on the sensor's sensitivity curve characteristics available in the datasheet [17]. One simple linear approach widely used for rough estimation is:

$$\text{Concentration (ppm)} = \frac{ADC_{value}}{1023} \times 1000 \quad (1)$$

Using this formula, the ADC values in the experimental data can be converted as follows: 623 => 609 ppm, 446 => 436 ppm, 394 => 385 ppm, 360 => 352 ppm, 332 => 325 ppm, 177 => 173 ppm.

The MQ2 and DHT22 sensors accurately detected changes in smoke gas concentration and environmental conditions in a simulated open waste burning [10]. At a distance of 30 cm, the smoke concentration reached approximately 609 ppm, indicating hazardous pollution [18]. The air temperature increased to 28.8°C, and humidity dropped to 91.2% due to the influence of heat and smoke.

Smoke gas levels decreased significantly with increasing distance from the combustion source. At a distance of 150 cm, the smoke concentration dropped to approximately 325 ppm, the air temperature stabilized at 26.9°C, and humidity rose to 97.4%. These data indicate that smoke and heat emissions spread and dilute in the air with distance.[19] Table 1 presents data on smoke concentration, temperature, and humidity at various distances from the combustion source. These data were obtained from six measurement points representing environmental conditions around the waste incineration site.

Table 1. MQ2 and DHT22 sensor reading data for waste burning smoke samples

No	Sample	Distance (cm)	Value	Concentration (ppm)	Status	T (C)	Humidity (%)
1.	Standard	-	177	173	Save	26,8	99,9
2.	Smoke from burning trash	30	623	609	Danger	28,8	91,2
3.	Smoke from burning trash	60	446	436	Danger	27,2	92,9
4.	Smoke from burning trash	90	394	385	Danger	26,9	94,4
5.	Smoke from burning trash	120	360	352	Danger	26,9	97,1
6.	Smoke from burning trash	150	332	325	Danger	26,9	97,4

### 3.1.2 Correlation of Distance to Smoke Concentration

The data shows a relationship between distance and the smoke index. The closer the sensor is to the smoke source, the higher the detected smoke index value.

At a distance of 30 cm, the index reaches 623 (approximately 609 ppm), while at a distance of 150 cm it decreases to 332 (approximately 325 ppm). This aligns with the basic principle of gas diffusion, where gas concentration decreases with distance due to mixing with clean air and environmental turbulence [20]. This situation demonstrates that open burning of waste can pollute the air quickly and over a significant radius. Although concentration decreases with distance, pollution levels remain in the "dangerous" category (>300 readings), even at 150 cm [21-22].

### **3.1.3 Correlation of Distance to Temperature**

The experimental results show that the temperature increases slightly at closer distances to the smoke source. The highest temperature increase occurred at a distance of 30 cm, reaching 28.8°C, while the temperature decreased to 26.9°C at a distance of 150 cm. This temperature increase can be attributed to the release of heat energy from the combustion process, which propagates through convection and radiation [23]. However, the temperature difference across distances was relatively small (<2°C), indicating that the heat effect of combustion is limited and tends to dissipate quickly in the open air, especially if the environment has good air circulation [24].

### **3.1.4 Correlation of Distance to Humidity**

The trend of humidity versus distance was not entirely linear, unlike the smoke concentration. Air humidity tended to be lower at close distances (91.2% at 30 cm) and higher at long distances (97.4% at 150 cm), with a maximum value of 99.9% at the control device. This decrease in humidity was likely caused by two factors: first, an increase in local temperature, which can lower the relative humidity (RH); and second, hot smoke particles disrupting the water vapor balance in the air [25]. Nevertheless, all humidity values were above 90%, indicating that the experiments were conducted in humid conditions. The DHT22 sensor is sensitive to changes in temperature and water vapor, so these differences remain relevant for analysis [26].

### **3.1.5 Relationships between Parameters**

The smoke index, temperature, and humidity are the main indicators affected by distance from the pollution source. Smoke concentrations are typically high near the emission source and decrease with distance [27]. Temperature tends to increase due to the heat from combustion, then gradually decreases [28]. Relative humidity can decrease due to the influence of heat, but stabilizes as distance from the source [29-30]. To illustrate the relationship between these three

parameters and distance, Figure 2 presents a diagram showing the trend of changes in each parameter at various measurement distances from the smoke source of waste combustion.



Figure 2. Relationship between Distance and Smoke Index, Temperature, and Humidity

The graph shows a significant decrease in the smoke index with increasing distance from the pollutant source, from 623 ppm at 30 cm to 332 ppm at 150 cm. This decrease is in accordance with the principle of gas diffusion, which causes concentration to decrease with distance [31]. The air temperature measured by the DHT22 sensor also decreased, from 28.8 °C at 30 cm to 26.9 °C at 150 cm, because the sensor is closer to the combustion heat source at a closer distance [32]. Air humidity actually increased from 91.2% at 30 cm to 97.4% at 150 cm, influenced by heat and smoke that cause high evaporation near the source, resulting in low relative humidity [33]. Overall, the data shows a negative correlation between distance and the smoke index and temperature, and a positive correlation with humidity, confirming that distance influences the level of pollution, temperature, and humidity in the microenvironment [34].

### 3.2 Analysis of the Effect of Distance from Emission Sources on Pollution Concentrations, Temperature, and Humidity in Motor Vehicle Combustion Smoke Samples

#### 3.2.1 General Analysis

The measurement data show that the highest smoke gas concentration occurs at a distance of 30 cm from the emission source, with a value of 344 ppm, which is categorized as hazardous. The gas concentration decreases with increasing distance from the source, reaching 108 ppm at a distance of 120 cm, which is considered safe. For comparison, the gas concentration in the untreated sample was recorded at only 87 ppm, indicating that the presence of motor vehicle exhaust significantly increases the levels of hazardous gases in the air. This finding supports the importance of controlling vehicle emissions and establishing safe zones for the public from direct exposure to combustion smoke [35].

The measurement results are presented in Table 2. Data were obtained from five measurement points representing environmental conditions at different distances from the local pollution source, namely motor vehicle combustion flames.

Table 2. MQ2 and DHT22 Sensor Readings from Motor Vehicle Combustion Smoke Samples

No	Sample	Distances (cm)	Value	Concentration (ppm)	Status	T (C)	Humidity (%)
1.	Standard	-	89	87	Save	31,6	76,8
2.	Smoke emissions	30	352	344	Danger	33,8	70,3
3.	Smoke emissions	60	304	297	Danger	33,5	70,4
4.	Smoke emissions	90	249	243	Save	33,0	70,8
5.	Smoke emissions	120	111	108	Save	33,0	74,9

### 3.2.2 Correlation of Distance to Smoke Concentration

The closer the device is to the emission source, the higher the detected smoke gas concentration. At a distance of 30 cm, the gas concentration reaches 344 ppm and is classified as hazardous. When the distance is increased to 60 cm, 90 cm, and 120 cm, the concentration decreases to 297 ppm, 243 ppm, and 108 ppm, respectively. This decrease indicates a strong relationship between distance and gas concentration. This decrease is caused by the process of gas dispersion in the air, where gas molecules spread out and mix with clean air as the distance from the source increases. This pattern also aligns with the principle of diffusion, which states that the concentration of combustion gases decreases significantly at greater distances from the emission source [36].

### 3.2.3 Correlation of Distance to Temperature

There is a tendency for air temperature to increase as the device is moved closer to the pollution source. The highest temperature was recorded at 30 cm, at 33.8°C, then gradually decreased to 33.5°C, 33.0°C, and remained at 33.0°C at distances of 60 cm, 90 cm, and 120 cm. The control temperature on the untreated device was 31.6°C. This temperature increase could be due to the heat effect of vehicle combustion, which produces localized heat energy. However, the temperature difference across distances was not significant (<2°C), indicating that temperature is only slightly affected by proximity to the smoke source. Nevertheless, temperature remains an important variable in atmospheric chemical reactions, particularly in determining the stability of gaseous compounds and the humidity of the surrounding air [37].

### 3.2.4 Correlation of Distance to Humidity

In contrast to concentration and temperature, air humidity shows an increasing trend with increasing distance from the smoke source. At a distance of 30 cm, humidity was recorded at 70.3% and continued to rise to 70.4%, 70.8%, and 74.9% at distances of

60 cm, 90 cm, and 120 cm, respectively. The highest humidity value was found in the control device (without exposure), at 76.8%. The decrease in humidity at close range is likely due to higher temperatures, which accelerate water evaporation, thus reducing the water vapor content in the air. Conversely, at greater distances, the air is more stable and better able to maintain its natural humidity [38].

### 3.2.5 Relationships Between Parameters

To test the effect of distance on air quality due to exhaust fumes from motor vehicles, three main parameters were measured: exhaust gas concentration (ppm), temperature ( $^{\circ}\text{C}$ ), and humidity (%). Measurements were conducted at five different distances from the emission source: 0 cm, 30 cm, 60 cm, 90 cm, and 120 cm. The data are presented in horizontal bar graphs to illustrate the relationship between distance and changes in the values of each parameter and to evaluate the decrease in pollution intensity with increasing distance from the pollutant source.



Figure 3. Relationship between Distance and Smoke Index, Temperature, and Humidity

The graph shows the highest smoke concentration (344 ppm) at 30 cm from the emission source, then decreasing to 108 ppm at 120 cm. For comparison, the device without a sample recorded only 87 ppm, indicating a significant influence from the emission source. This decrease reflects the diffusion and dilution processes of particles in the air, in line with the principle of pollutant dispersion. The measured temperature was relatively stable, ranging from  $31.6^{\circ}\text{C}$  to  $33.8^{\circ}\text{C}$ , with a peak at 30 cm. This increase was caused by the thermal energy of the exhaust gas. As the distance increased, the temperature decreased due to heat release and air convection. Humidity showed the opposite trend, reaching its highest at 0 cm (76.8%), decreasing to 70.3% at 30 cm, and then increasing again to 74.9% at 120 cm. This decrease was likely triggered by hot steam from combustion reducing the water vapor content in the surrounding air. There was a linear relationship between distance and smoke concentration: the farther from the source, the

lower the level. Temperature shows a weak but significant correlation, while humidity fluctuates temporarily before stabilizing. These three parameters reflect a decline in air quality near the emission source that improves with distance.

#### 4. CONCLUSION

Measurements show that distance significantly influences smoke concentration. The closer the device is to the combustion source, the higher the detected smoke levels. For waste burning, smoke concentrations reached 609 ppm at a distance of 30 cm, which is considered hazardous. For vehicle exhaust, the peak was 341 ppm at the same distance, then decreased to 110 ppm at 120 cm. This confirms the dilution of pollutants with increasing distance. Temperature and humidity parameters also changed with distance, although not as fluctuatingly as for smoke. Temperature decreased from 28.8°C to 26.9°C for waste burning, and from 33.1°C to 30.7°C for vehicle exhaust. This decrease was due to heat from the emission source diffusing into the environment. Conversely, humidity increased from 91.2% to 97.4% and 65% to 71%, likely due to a reduction in pollutant particles absorbing water vapor. Overall, distance from the pollutant source significantly determines air quality. Maintaining a safe distance helps reduce the concentration of hazardous smoke and maintains stable temperature and humidity. Thus, this step is important to prevent negative impacts on health and the surrounding environment.

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