



Smart Air Quality Analysis Using Fuzzy Logic for Health Risk Prevention

Aidil Fitriyah Fadwi^{1*}

¹Politeknik Negeri Sriwijaya

aidilfitriyah03@gmail.com

Abstract

This study examines an intelligent system for analyzing air quality using fuzzy logic as a decision-making tool to reduce health risks. The system is designed to monitor air quality in real-time and calculate the Air Quality Index (AQI) accurately. By applying the Mamdani method, this system is able to predict the level of air pollution and identify conditions that have the potential to endanger human health. Through processing uncertain and ambiguous data, fuzzy logic helps provide a more precise interpretation of the environmental situation. The analysis results of this system also provide recommendations for actions that need to be taken to prevent the adverse effects of air pollution. Continuous monitoring allows users to obtain direct information regarding the condition of the surrounding air, so that prevention can be carried out more quickly and precisely. This system plays an important role in supporting efforts to protect public health proactively.

Keywords: Air, Public Health, Monitoring, Real-Time, Internet of Things

1. Introduction

Air quality issues have become a global concern due to their impact on human health. In indoor environments, pollutants such as carbon monoxide (CO), carbon dioxide (CO₂), ammonia (NH₃), and benzene can accumulate due to household activities, such as the use of electric mosquito repellent or air fresheners. Repeated exposure to polluted air increases the risk of chronic diseases, especially respiratory disorders. Therefore, a system is needed that is able to monitor and analyze air quality intelligently and in real-time.

This study aims to design an air quality monitoring system that utilizes MQ135 sensors (for detecting hazardous gases) and DHT22 (for temperature and humidity), and implements fuzzy logic as a classification method. This system functions as a decision support tool in responding to unhealthy air conditions by providing warning signals or recommendations for preventive actions. This approach is expected to increase awareness and control of environmental factors that pose a risk to health. The World Health Organization (WHO) states that there are hazardous substances originating from building waste emissions, construction materials, equipment, combustion or heating processes that can trigger health problems[1]

The system developed in this study is also equipped with an Internet of Things (IoT)-based monitoring feature using a platform such as Blynk, allowing users to access air quality data remotely via mobile devices. Data obtained from sensors will be processed using the fuzzy logic method to determine the level of air quality in the good, moderate, or bad categories based on parameters. Classification results information is displayed in real-time, accompanied by notifications, LEDs and buzzers for quick response. With the integration of this technology, the system is not only reactive, but also proactive in supporting public health protection in closed environments such as homes, offices, or study rooms.

2. Literature Review

2.1. ESP 32 Microcontroller

ESP32 is a WiFi and Bluetooth chip-based microcontroller developed by Espressif Systems which has several main advantages, namely capable of wireless connectivity via WiFi 802.11 b/g/n and Bluetooth 4.2 which enables real-time data transmission. Second, efficient power consumption with various energy saving modes. Third, support for various communication protocols such as SPI, I2C, and UART which facilitate integration with environmental sensors. In the context of this research, ESP32 acts as the main controller that regulates the process of data retrieval from sensors, performs fuzzy logic computations, and sends analysis results to the central monitoring system.

2.2. Sensor MQ-135

MQ135 is a semiconductor-based gas sensor capable of detecting various air pollutants such as ammonia (NH₃), benzene, and carbon dioxide (CO₂). Its working principle is based on changes in the resistance of tin-oxide (SnO₂)-based sensing material when interacting with target gas molecules. Technically, this sensor has important characteristics including: 5V DC operating voltage, sensitivity to gas concentrations of 10-1000 ppm, a minimum heating time of 24 hours to achieve measurement stability, and resistance in a temperature range of -10°C to 50°C with a maximum humidity of 95% RH. This sensor uses an internal heating system to activate the sensing material and produce an analog signal that is proportional to the concentration of the detected gas. In its implementation, the MQ135 requires calibration against environmental factors such as temperature and humidity to ensure measurement accuracy. This sensor has good durability for use as a pollution hazard marker because it is practical and does not consume a lot of power[2].

2.3. Sensor DHT 22

DHT22 is a digital sensor used to measure temperature and humidity. This sensor is capable of reading temperatures from -40°C to 80°C with an accuracy of ±0.5°C, and humidity from 0% to 100% RH with an accuracy of ±2–5% RH. Using one-wire communication, DHT22 facilitates integration with microcontrollers such as ESP32. DHT22 uses sensitive polymer materials for humidity and thermistors for temperature, thus providing important data in air quality monitoring systems. This temperature and humidity information is useful in analyzing the effect of the environment on pollutant concentrations.

2.4. Buzzer

A buzzer is an electronic component that produces sound in response to an electrical signal. There are two main types: active buzzers that work directly with voltage, and passive buzzers that require a frequency signal. In air quality monitoring systems, buzzers are used as alarms to notify users when pollution levels exceed a threshold. A microcontroller such as the ESP32 can activate a buzzer when it detects bad air. Buzzers are effective because their sound is easily recognizable, small in size, and low in cost, making them suitable for environmental warning systems.

2.5. LED

Light Emitting Diode (LED) is a semiconductor component that produces light when passed through an electric current in a forward bias condition. LEDs have a working voltage of between 1.8V to 3.3V and a long service life, reaching 25,000 to 100,000 hours. LEDs are known to be energy efficient, fast-responding, and resistant to vibration, making them suitable as a communication medium between the system and the user.

2.6. LCD Display

LCD (Liquid Crystal Display) is an electronic display device that utilizes liquid crystals to display characters when an electric current is passed through it. LCDs are widely used in microcontroller systems because they have low power consumption and compact size. Commonly used LCD types, such as 16x2 and 20x4 LCDs, can display enough information to provide real-time environmental status. With a simple interface, such as I2C, LCDs can be easily integrated with microcontrollers such as the ESP32. The use of LCDs increases user interaction with the system, because information is displayed clearly without requiring connections to other devices.

2.7. Fuzzy Logic

Fuzzy Logic is a logic method developed to handle uncertainty and ambiguity in the decision-making process. Unlike conventional binary logic that only recognizes two values, namely true or false, fuzzy logic allows values to be in the range of 0 to 1. This makes it more capable of representing complex information and resembles the way humans think. In a fuzzy system, input data is converted into a fuzzy set using a membership function that determines the extent to which the value belongs to a category. The process consists of three main stages: fuzzification (converting input data into degrees of membership), rule application (using a fuzzy rule base to generate decisions), and defuzzification (converting fuzzy results into numeric outputs that can be used directly). Fuzzy logic is used to translate a quantity expressed using language (linguistics), for example the quantity of vehicle speed expressed as slow, quite fast, fast, and very fast[3].

2.8. Internet of Things (IoT)

The term “Internet Of Things” consists of two main parts of the word, namely the Internet which connects and regulates connectivity and Things which means an object or a device. Simply put, you have “Things” that can be connected to each other to collect data and send it to the Internet. This data can also be accessed by other “Things” too. where a certain “Thing” has the ability to send data through the network wherever you are and without any interaction from human to human or from human to computer devices[4].

3. System Design

This chapter discusses the design stage of an air quality monitoring system based on fuzzy logic and IoT. The design is carried out to describe how the system works as a whole, starting from the process flow, the relationship between components, to the physical form of the device. This chapter presents a block diagram that shows the main structure of the system, a flowchart as a representation of the program logic flow, and a 3D design of the device as a visualization of the hardware design. This design is the basis for implementing the tool so that the system can function according to its purpose, namely monitoring air conditions in real-time and responding to changes in air quality detected by the sensor.

3.1. Block Diagram

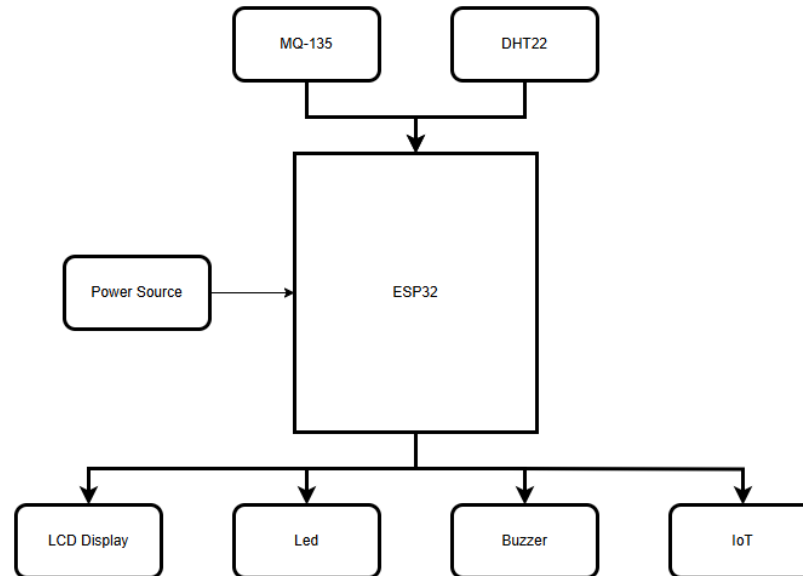


Fig. 1: Block diagram air quality monitoring

The diagram above illustrates an integrated monitoring system using the ESP32 module as a microcontroller. This system receives input from two sensors, namely MQ-135 and DHT22. The MQ-135 sensor functions to detect air quality by measuring the concentration of hazardous gases, while the DHT22 sensor measures temperature and humidity. All data obtained will be processed by the ESP32, which is also connected to a power source for electricity. The results of data processing can then be displayed on several outputs, including an LCD Display for direct visualization, an LED as a status indicator, a buzzer to provide sound alerts, and a connection to IoT to send information to an online platform. With this system, users can monitor environmental conditions in real-time and make decisions based on accurate data.

3.2. Wiring Diagram

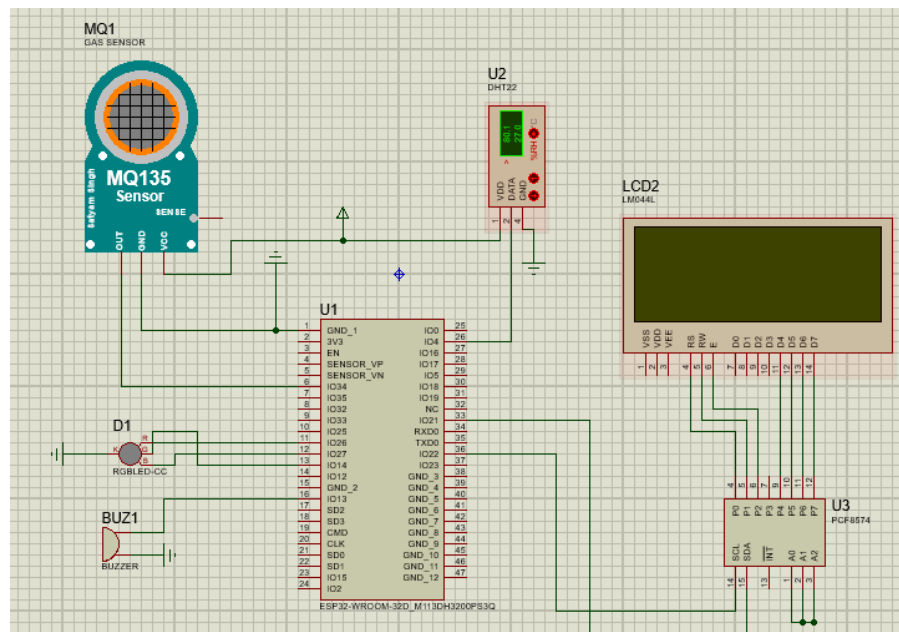


Fig. 2: Wiring diagram air quality monitoring

The wiring diagram above shows the ESP32-based air quality monitoring system circuit. The MQ135 sensor is used to detect air quality (hazardous gases), while the DHT22 sensor is used to measure ambient temperature and humidity. Data from both sensors is sent to the ESP32 microcontroller (U1), which then displays the results to the I2C LCD for easy reading. The circuit is also equipped with an LED indicator (D1) and a buzzer (BUZ1) as an alarm output to indicate unhealthy air conditions based on programmed fuzzy logic.

3.3. Flowchart

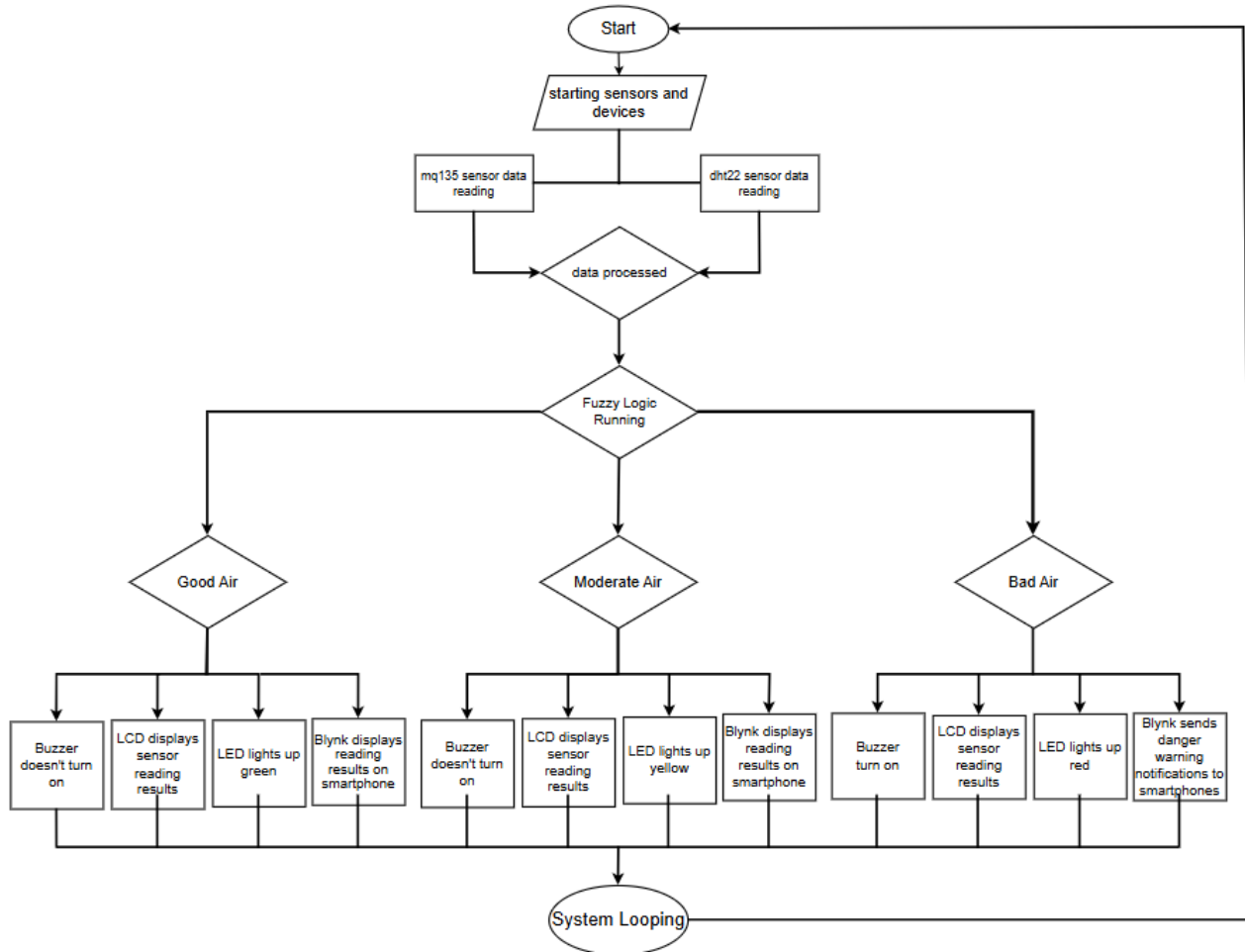


Fig. 3: Flowchart air quality monitoring

The flowchart above illustrates the workflow of the MQ135 and DHT22 sensor-based air quality monitoring system processed using fuzzy logic. The process begins with reading data from both sensors, then the data is processed and analyzed by the fuzzy logic system to determine the level of air quality: good, moderate, or bad. Based on the analysis results, the system will provide different responses, such as displaying the results on the LCD, turning on the LED with a certain color (green, yellow, or red), activating the buzzer if the air is bad, and sending notifications to smartphones via Blynk. After one cycle is complete, the system will continue to repeat the process in a loop.

3.4. Air Quality Parameters

Rentang	Kategori	Penjelasan
1-50	Baik	Tingkat mutu udara yang sangat baik, tidak memberikan efek negative terhadap manusia, hewan dan tumbuhan.
50-100	Sedang	Tingkat mutu udara masih dapat diterima pada kesehatan manusia, hewan dan tumbuhan.
100-200	Tidak Sehat	Tingkat mutu udara yang bersifat merugikan pada manusia, hewan dan tumbuhan.
201-300	Sangat Tidak Sehat	Tingkat mutu udara yang dapat meningkatkan resiko kesehatan pada sejumlah segmen populasi yang terpapar.
>300	Berbahaya	Tingkat mutu udara yang dapat merugikan kesehatan serius pada populasi dan perlu penanganan cepat.

Fig. 4: Index air quality system

In 2020, the Ministry of Environment and Forestry issued Regulation of the Minister of Environment and Forestry Number 14 of 2020 concerning the Air Pollutant Standard Index concerning Calculation and Reporting as well as Information on the Air Pollutant Standard Index, which can be seen in the table above[5].

4. Results and Discussion

4.1. Testing

In this tool test, I conducted a trial in a closed room measuring 3m x 2.5m with a room height of m, this room was chosen to ensure that environmental conditions remain stable and are not affected by outside air. There are 3 samples that will be tested, mosquito coils, cigarette smoke and air freshener spray. Each sample will have its data taken at seconds 0, 15, 30, 45, 60. The data collected will be used to analyze changes in air quality gradually and evaluate the performance of fuzzy logic-based monitoring tools in detecting air conditions.

1. Mosquito Coils

Table 1: Test data results from mosquito coil samples

SAMPLE	WAKTU (Second)	KADAR POLUTAN	KETERANGAN
Mosquito Coils	0 s	72 ppm	Baik
	15 s	244 ppm	Sedang
	30 s	431 ppm	Buruk
	45 s	495 ppm	Buruk
	60 s	535 ppm	Buruk

2. Cigarette Smoke

Table 2: Test data results from cigarette smoke samples

SAMPLE	WAKTU (Second)	KADAR POLUTAN	KETERANGAN
Cigarette Smoke	0 s	83 ppm	Baik
	15 s	181 ppm	Sedang
	30 s	337 ppm	Buruk
	45 s	442 ppm	Buruk
	60 s	502 ppm	Buruk

3. Air Freshener Spray

Table 3: test data results from air freshener spray samples

SAMPLE	WAKTU (Second)	KADAR POLUTAN	KETERANGAN
Air Freshener Spray	0 s	63 ppm	Baik
	15 s	153 ppm	Sedang
	30 s	237 ppm	Sedang
	45 s	349 ppm	Buruk
	60 s	292 ppm	Sedang

5. Conclusion

Based on the results of the trial on three types of samples, namely mosquito coil smoke, cigarette smoke, and air freshener spray, it was found that mosquito coil smoke produced the highest pollutant levels with a significant increase from 72 ppm at second 0 to 535 ppm at second 60. Air quality began to be categorized as poor from second 30 to the end of the measurement. Cigarette smoke also showed a high increase in pollutant levels, from 83 ppm to 442 ppm by second 45, indicating that cigarette smoke is classified as hazardous air pollution, although slightly lower than mosquito coil smoke. Meanwhile, air freshener spray produced lower pollutant levels than the previous two samples, with a peak reaching 349 ppm at second 45 (bad category), but then decreasing to 292 ppm at second 60, returning to the moderate category. This shows that although air freshener spray can pollute the air in the short term, its concentration tends to decrease more quickly than cigarette smoke or mosquito coils. From the three samples, it can be concluded that mosquito coil smoke is the most dangerous source of air pollution in this test, followed by cigarette smoke, and the one with the lightest impact and the quickest relief is air freshener spray.

References

- [1] "World Health Organization Regional Office for Europe SELECTED POLLUTANTS." [Online]. Available: www.euro.who.int
- [2] A. A. Rosa, B. A. Simon, and K. S. Licanto, "Sistem Pendeteksi Pencemar Udara Portabel Menggunakan Sensor MQ-7 dan MQ-135," *ULTIMA Computing*, vol. XII, no. 1, 2020.
- [3] P. Studi Teknik Informatika Jurusan Teknik Elektro, "Implementasi Logika Fuzzy pada Sistem Kecerdasan Buatan Helfi Nasution," 2012.
- [4] A. Selay *et al.*, "INTERNET OF THINGS," 2022.
- [5] "Permen LHK Nomor 14 Tahun 2020," 2020.
- [6] I. El, A. Pakpahan, dan U. Hasibuan, "Analisis Kinerja Sensor DHT11 Pada Alat Pendeteksi Suhu Menggunakan Metode Fuzzy Logic," *JIK TEKS: Jurnal Ilmu Komputer dan Teknologi Informasi*, vol. 03, no. 01, 2024, doi: 10.70404/jikteks.v3i01.144.

-
- [7] Z. Majidah, M. Ari Bianto, dan B. Dwi Saputra, "Implementasi Fuzzy Logic Mamdani Untuk Monitoring Kualitas Udara Berbasis Iot," *Jurnal Pengembangan Teknologi Informasi dan Komunikasi (JUPTIK)*, vol. 2, no. 1, hlm. 1–6, Jun 2024, doi: 10.52060/juptik.v2i1.2091.
- [8] T. Tamaji dan Y. A. K. Utama, "IMPLEMENTASI FUZZY LOGIC UNTUK KUALITAS UDARA, SUHU, DAN KELEMBABAN UDARA BERBASIS IOT," *Foristek*, vol. 14, no. 1, Jun 2023, doi: 10.54757/fs.v14i1.249