Journal of Artificial Intelligence and Engineering Applications

Website: https://ioinformatic.org/

15th February 2026. Vol. 5. No. 2; e-ISSN: 2808-4519

Air Quality Monitoring System for Hazardous Gas Detection and Fire Risk in a Chemical Laboratory

Vergi Ramadhani[1]*, Syarifah Aini[2], Jimmie[3]

[1,2,3]*Information Technology Study Program, Faculty of Engineering, Muhammadiyah University of Palembang, Indonesia*
vergiramadani6@gmail.com [1*], Ainiuzumakiandriyos@gmail.com [2], Jimmie@um-palembang.com [3]

Abstract

Chemical laboratories require a safe and controlled environment due to the frequent use of hazardous and flammable substances that may pose serious health and fire risks. Inadequate air quality monitoring can increase the likelihood of gas exposure and uncontrolled fire incidents. This study focuses on the development of an air quality monitoring system for detecting hazardous gases and fire risk in a chemical laboratory. The proposed system is based on an Internet of Things approach using a NodeMCU ESP8266 microcontroller integrated with an MQ-135 gas sensor and a DHT11 temperature sensor. Environmental data are monitored in real time and displayed locally through an I2C LCD as well as remotely via the Blynk application. Experimental evaluation shows that the system is able to detect abnormal gas concentrations and temperature variations that indicate potential hazardous conditions. The results demonstrate that the proposed system can function as an effective early warning tool to support safety management and risk mitigation in chemical laboratory environments.

Keywords: *Air quality monitoring, Chemical laboratory, Fire risk detection, Hazardous gas, Internet of Things*

1. Introduction

Chemical laboratories play a critical role in supporting education, research, and technological development, particularly in engineering and applied sciences[1] [2]. These environments frequently involve the use of hazardous, toxic, and flammable substances that may pose serious risks to human health and laboratory infrastructure if not properly controlled[3]. Gas leakage and uncontrolled temperature increases are among the most common factors contributing to laboratory accidents, including poisoning, explosions, and fires[4].

Maintaining safe air quality conditions in chemical laboratories is therefore an essential aspect of occupational safety management[5]. Conventional safety measures often rely on periodic inspections and manual monitoring, which may not be sufficient to provide immediate detection of hazardous gas exposure or early signs of fire risk[6]. Delays in identifying abnormal environmental conditions can significantly increase the severity of accidents and potential damage[7].

Recent advancements in sensing technology and Internet of Things (IoT) systems have enabled the development of real-time environmental monitoring solutions [8]. IoT-based monitoring systems allow continuous data acquisition, remote access, and early warning capabilities, making them suitable for safety-critical environments such as chemical laboratories [9]. By integrating gas sensors, temperature sensors, and wireless communication modules, such systems can provide timely information to laboratory personnel for preventive action [10].

This study proposes an air quality monitoring system designed to detect hazardous gases and fire risk in a chemical laboratory environment. The system utilizes a NodeMCU ESP8266 microcontroller integrated with an MQ-135 gas sensor and a DHT11 temperature sensor to monitor air quality and temperature conditions [11] [12]. Sensor data are displayed locally and transmitted wirelessly for remote monitoring [13]. The main objective of this research is to develop and evaluate a reliable and low-cost monitoring system that can function as an early warning tool to enhance safety management and risk mitigation in chemical laboratories.

2. Methods

This study uses a Design and Creation method with a qualitative approach to develop an IoT-based air quality monitoring system for hazardous gas detection and fire risk prevention in a chemical laboratory. The research stages include requirement analysis, system design, hardware and software implementation, and system testing[14]. The system integrates a NodeMCU ESP8266 with MQ-135 and DHT11 sensors, an LCD, LEDs, and a buzzer, and is programmed using the Arduino IDE with Blynk for real-time monitoring. System testing evaluates component performance and overall system functionality[15].

2.1. System architecture

The system architecture defines the overall structure and interaction between hardware components, communication modules, and monitoring applications in the proposed air quality monitoring system[16]. This architecture is designed to support continuous environmental data acquisition, real-time processing, and early warning functionality in a chemical laboratory environment. By adopting an Internet of Things (IoT) approach, the system enables seamless integration between physical sensing devices and remote monitoring platforms. Table 1 illustrates the IoT-based system architecture of the proposed monitoring system, showing how environmental data flow from the sensing layer to the processing and communication layer, and finally to the monitoring and alert layer.

Table 1: System Architecture

No	Component	Function	Input	Output
1	MQ-135 Gas Sensor	Detects hazardous gases such as ammonia, carbon monoxide, carbon dioxide, and nitrogen oxides	Air quality (gas concentration)	Analog gas value
2	DHT11 Sensor	Measures temperature and humidity in the chemical laboratory environment	Ambient temperature and humidity	Digital temperature and humidity data
3	NodeMCU ESP8266	Processes sensor data and controls system operations	Data from MQ-135 and DHT11 sensors	Control signals to LCD, LED, buzzer, and Blynk
4	LCD 16x2	Displays temperature, humidity, and system status information	Processed data from NodeMCU	Visual information output
5	LED (Red & Green)	Provides visual indication of air quality status	Control signal from NodeMCU	Red LED (Danger) / Green LED (Safe)
6	Buzzer	Acts as an audible alarm when hazardous conditions are detected	Control signal from NodeMCU	Sound alarm
7	Blynk Application	Monitors real-time sensor data and allows threshold adjustment	Sensor data from NodeMCU	User interface and updated threshold values

Based on the illustrated architecture, the system consists of a sensing layer that collects air quality and temperature data, a processing layer that evaluates environmental conditions using predefined thresholds, and a monitoring layer that provides local and remote visualization. This layered architecture ensures scalability, reliability, and effective safety monitoring for chemical laboratory environments.

2.2. Block diagram

The block diagram provides a functional representation of the proposed system, emphasizing the logical relationship between input sensors, processing units, and output devices. This diagram is essential to understanding how data are processed and how control decisions are generated within the system. Figure 1 presents the block diagram of the air quality monitoring system, where the MQ-135 gas sensor and DHT11 temperature sensor serve as input blocks, the NodeMCU ESP8266 functions as the central processing unit, and the display and alert modules act as output blocks.

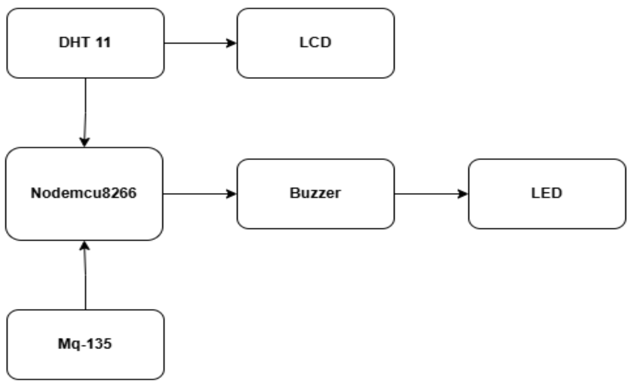

Fig. 1: Block diagram

As shown in the block diagram, sensor data are continuously transmitted to the microcontroller for processing and evaluation. When the detected values exceed safe limits, the system triggers visual and audible alerts and sends data to the remote monitoring application. This functional structure ensures efficient data handling and rapid response to hazardous conditions.

2.3. Hardware implementation

The hardware implementation focuses on the physical realization of the proposed system, including sensor integration, output devices, and display modules. Each component is selected based on functionality, compatibility, and reliability to ensure accurate monitoring and stable system operation. Table 2 lists the main hardware components used in the system along with their respective functions.

Table 2: Hardware components of the proposed system

No	Component	Function
1	NodeMCU ESP8266	Main controller and Wi-Fi communication
2	MQ-135 gas sensor	Detection of hazardous gas concentration
3	DHT11 sensor	Measurement of temperature
4	Buzzer	Audible warning indicator

5	Green LED	Safe condition indicator
6	Red LED	Hazardous condition indicator
7	I2C LCD (16×2)	Local display of environmental data

The listed hardware components work together to support real-time air quality monitoring and fire risk detection. The combination of environmental sensors, processing units, and alert indicators allows the system to operate effectively in laboratory conditions while maintaining a low-cost and modular design.

2.4. Pin configuration

Proper pin configuration is essential to ensure correct data transmission, power distribution, and output control within the system. The pin mapping between the NodeMCU ESP8266 and each connected component is carefully defined to avoid communication errors and ensure system stability. Table 3 shows the detailed pin configuration used in the proposed system.

Table 3: Pin Configuration

Component	Pin	NodeMCU Pin	Description
DHT11	Data	D4	Temperature data input
MQ-135	AO	A0	Gas concentration input
Buzzer	+	D7	Alarm output
Green LED	Anode	D5	Safe indicator
Red LED	Anode	D6	Hazard indicator
LCD I2C	SDA / SCL	D2 / D1	I2C communication

This pin configuration enables reliable sensor data acquisition and accurate activation of output devices. By clearly defining each pin connection, the system ensures consistent performance and simplifies future system maintenance or expansion.

2.5. System flowchart

The system flowchart illustrates the operational sequence of the proposed monitoring system, providing a clear overview of how data are processed from initialization to decision-making. This flowchart helps to visualize the logic used to detect hazardous conditions and trigger appropriate responses. Figure 2 shows the flowchart of the system operation, starting from system initialization, followed by continuous sensor data acquisition and threshold evaluation.

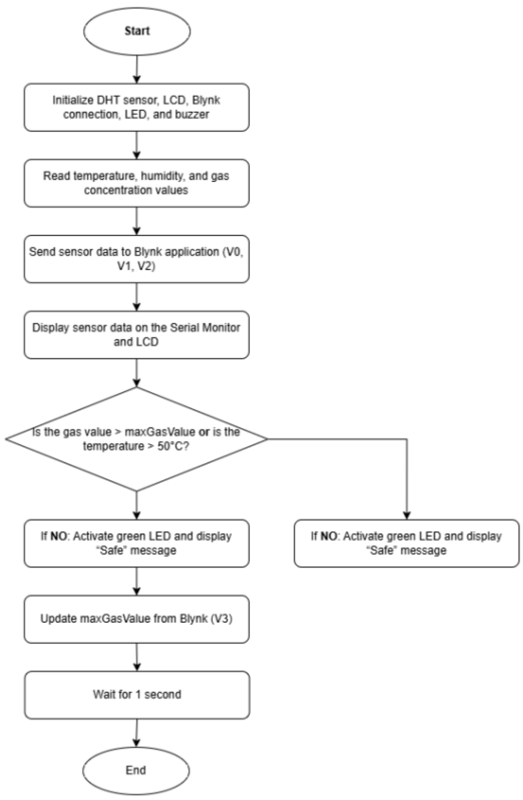

Fig. 2: System flowchart

Based on the flowchart, the system continuously monitors air quality and temperature conditions. When abnormal values are detected, warning indicators are activated and alert data are transmitted for remote monitoring. Otherwise, the system remains in normal monitoring mode, ensuring uninterrupted environmental supervision.

2.6. Research procedure

The research procedure is conducted through a structured sequence of stages to ensure systematic development and evaluation of the proposed system. The procedure begins with system requirement analysis and architectural design, followed by hardware assembly and software development. Individual components are tested to verify sensor accuracy and output responsiveness before full system integration.

After integration, the system undergoes experimental testing under controlled laboratory conditions to evaluate its performance in detecting hazardous gas exposure and fire-related risk indicators. The collected data are analyzed to assess system reliability, responsiveness, and overall effectiveness as a laboratory safety monitoring solution.

2.7. Tools and materials

The development and testing of the proposed air quality monitoring system require specific tools and materials to support hardware assembly, software programming, and system evaluation. These tools and components were carefully selected to ensure efficient implementation, stable system performance, and accurate experimental results.

Table 4: Tools and materials

Category	Description
Tools	Laptop, power supply
Materials	NodeMCU ESP8266, MQ-135, DHT11, buzzer, LEDs, I2C LCD, breadboard, jumper cables

The availability and proper utilization of the listed tools and materials enable the successful construction and testing of the monitoring system. Their use supports system reliability, facilitates repeatable testing procedures, and contributes to the overall validity of the research outcomes

3. Result and Discussion

This section presents the results of the system design, implementation, and testing of the IoT-based air quality monitoring system for hazardous gas detection and fire risk mitigation in a chemical laboratory. The discussion focuses on the performance of the developed system in monitoring gas concentration, temperature, and humidity, as well as its ability to provide real-time information and early warning alerts in accordance with the research objectives.

3.1. System Testing

System testing was conducted to evaluate the performance of each hardware and software component used in the air quality monitoring system. The testing process aimed to ensure that all sensors, output devices, and the controller operated correctly both individually and as an integrated system. Figure 3 presents the hardware system testing setup used to evaluate the performance of the integrated air quality monitoring system.

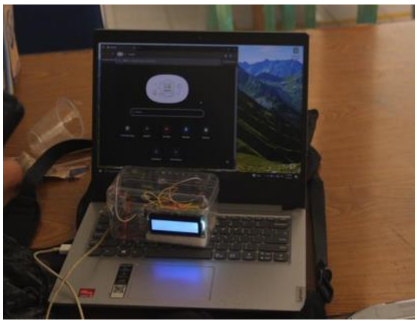

Fig. 3: Hardware System Testing

As shown in Figure 3, the system testing configuration consists of the NodeMCU ESP8266 connected to the MQ-135 gas sensor, DHT11 temperature and humidity sensor, LCD 16×2 display, buzzer, and LED indicators. This configuration illustrates the physical integration of all hardware components during the testing phase. The testing setup was used to verify proper power distribution, signal communication, and coordinated system responses under different environmental conditions. The results confirm that the integrated hardware components operate simultaneously and support reliable detection, monitoring, and early warning functions within the chemical laboratory environment.

3.1.1. MQ-135 Gas Sensor Testing Results

The MQ-135 sensor was utilized to detect air quality conditions in the chemical laboratory environment. This sensor responds to various gases such as ammonia (NH_3), carbon dioxide (CO_2), carbon monoxide (CO), and nitrogen oxides (NOx) by changing its conductivity according to the detected gas concentration. The purpose of this test was to verify the ability of the MQ-135 sensor to detect changes in air quality within the laboratory.

The testing setup consisted of the MQ-135 sensor connected to the NodeMCU ESP8266 using jumper cables and programmed through the Arduino IDE. The sensor's VCC, GND, and analog output (AO) pins were connected according to the system design. Based on the test results, the MQ-135 sensor operated in accordance with the programmed instructions. The sensor successfully detected variations in air quality, as indicated by changes in analog output values processed by the NodeMCU ESP8266. These results confirm that the MQ-135 sensor is suitable for detecting hazardous gas presence in a chemical laboratory environment.

3.1.2. DHT11 Temperature and Humidity Sensor Testing Results

The DHT11 sensor was tested to measure ambient temperature and humidity levels in the laboratory. This sensor integrates temperature and humidity sensing in a single module and provides calibrated digital output signals. The objective of this test was to ensure that the DHT11 sensor could accurately read temperature and humidity data.

During testing, the DHT11 sensor was connected to the NodeMCU ESP8266 via the 3.3 V power supply, ground pin, and a digital data pin. The sensor readings were processed using a program developed in the Arduino IDE. The results showed that the DHT11 sensor functioned properly and consistently delivered temperature and humidity data to the NodeMCU ESP8266. These values were successfully interpreted by the system, indicating that the sensor is reliable for monitoring environmental conditions related to fire risk in laboratory settings.

3.1.3. LCD 16×2 Display Testing Results

The LCD 16×2 module was tested to evaluate its capability to display system monitoring data. The display module is designed to show temperature, humidity, and system status information obtained from the DHT11 sensor and processed by the NodeMCU ESP8266. The LCD was connected to the NodeMCU using the I2C communication interface, which reduces the number of required input/output pins. During testing, the LCD received data commands from the microcontroller and displayed sensor readings in real time. The test results indicate that the LCD 16×2 module functioned correctly and displayed temperature and humidity values accurately. This confirms that the LCD is effective as a local monitoring interface, allowing users to directly observe environmental conditions inside the laboratory.

3.1.4. Buzzer and LED Testing Results

The buzzer and LED indicators were tested as part of the system's alarm mechanism. Both components serve as warning indicators, with the buzzer providing an audible alert and the LEDs providing visual notifications. In the testing process, the buzzer and LEDs were connected through a breadboard and controlled by the NodeMCU ESP8266. When hazardous gas conditions were simulated or detected by the MQ-135 sensor, the system activated the red LED and buzzer. Conversely, under safe air quality conditions, the green LED was activated. The results demonstrate that the buzzer and LED indicators responded correctly to the system commands. This confirms that the alarm components function effectively in providing early warnings of hazardous gas exposure.

3.2. Overall System Testing Results

To provide a clearer overview of the system performance, a summary of the testing results for each system component is presented in Table 5. This table highlights the functionality status and testing outcomes of all hardware components used in the proposed air quality monitoring system.

Table 5: Summary of system testing results

Component	Test Parameter	Expected Result	Actual Result	Status
MQ-135 Sensor	Gas concentration detection	Value increases when gas is present	Gas value increased proportionally	Pass
DHT11 Sensor	Temperature & humidity reading	Stable digital output	Accurate temperature & humidity data	Pass
LCD 16×2	Data display	Displays temperature & gas values	Data displayed correctly	Pass
Buzzer	Alarm activation	Active when threshold exceeded	Activated as programmed	Pass
LED Indicator	Visual warning	Red for danger, green for safe	Functioned correctly	Pass
Blynk App	Real-time monitoring	Data transmitted successfully	Data updated in real time	Pass

Following individual component testing, the entire air quality monitoring system was evaluated as a fully integrated unit. All components, including the MQ-135 gas sensor, DHT11 temperature and humidity sensor, LCD display, buzzer, LED indicators, and NodeMCU ESP8266 controller, were supplied with appropriate voltage levels to ensure stable and reliable operation. Fig. 4. Overall hardware implementation of the IoT-based air quality monitoring system.

Fig. 4: Overall hardware implementation of the IoT-based air quality monitoring system

Figure 4 illustrates the complete hardware configuration used during overall system testing. This testing phase aimed to verify whether all integrated components could operate simultaneously and respond appropriately to varying environmental conditions. The results demonstrate that the system successfully detected hazardous gas concentrations and activated the red LED and buzzer as early warning indicators. Under normal air quality conditions, the green LED remained active, indicating a safe environment.

In addition, when the ambient temperature measured by the DHT11 sensor exceeded the predefined threshold, the system triggered the buzzer to indicate a potential fire risk. These findings confirm that the integration of gas concentration and temperature thresholds enhances the reliability of the warning mechanism. The dual-parameter detection approach effectively minimizes false alarms caused by temporary environmental fluctuations and improves early fire risk identification in chemical laboratory environments.

4. Conclusion

This study successfully developed and implemented an IoT-based air quality monitoring system for hazardous gas detection and fire risk mitigation in a chemical laboratory environment. The proposed system integrates the MQ-135 gas sensor, DHT11 temperature and humidity sensor, NodeMCU ESP8266, LCD display, buzzer, LED indicators, and the Blynk platform to provide real-time monitoring and early warning capabilities. The main contribution of this research lies in the integration of environmental sensing and real-time notification mechanisms to enhance laboratory safety through continuous monitoring and rapid response to hazardous conditions.

The implementation and testing results demonstrate that all system components function reliably and in accordance with the system design. The MQ-135 sensor effectively detects changes in air quality, while the DHT11 sensor provides consistent temperature and humidity readings relevant to fire risk assessment. The LCD display, buzzer, and LED indicators operate correctly as local warning interfaces, and the NodeMCU ESP8266 successfully processes sensor data and controls system outputs. Overall system testing confirms that the system can accurately trigger visual and audible alarms when predefined gas concentration or temperature thresholds are exceeded.

In conclusion, the developed system offers a practical and effective solution for improving safety monitoring in chemical laboratories by providing real-time environmental data and early warning alerts. This research contributes to the field of IoT-based safety systems by demonstrating the applicability of low-cost sensors and wireless communication for hazard detection and risk mitigation. Future work may focus on improving sensor calibration accuracy, adding data logging and analytics features, and integrating the system with institutional safety management platforms to enhance scalability and long-term monitoring capabilities.

Acknowledgement

The authors would like to express their sincere gratitude to the Information Technology Study Program, Faculty of Engineering, Universitas Muhammadiyah Palembang, for providing support, facilities, and guidance during the completion of this research. Appreciation is also extended to colleagues and academic staff who contributed valuable suggestions and assistance throughout the development and evaluation of the application. This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

References

[1] J. Praveenchandar *Et Al.*, "Iot-Based Harmful Toxic Gases Monitoring And Fault Detection On The Sensor Dataset Using Deep Learning Techniques," Vol. 2022, 2022, Doi: 10.1155/2022/7516328.
[2] Z. Tatli And A. Ayas, "Effect Of A Virtual Chemistry Laboratory On Students ' Achievement," Vol. 16, Pp. 159–170, 2013.
[3] I. G. A. Gunadi And D. O. Rahmawati, "Sistem Deteksi Gas Berbasis Teknologi Iot Arduino," *J. Ilmu Komput. Indones.*, Vol. 7, No. November, Pp. 26–35, 2022.
[4] E. Rahmawati And F. Aeni, "Sistem Deteksi Kebocoran Gas Berbasis Arduino Menggunakan Gas Detector," *J. Sarj. Tek. Inform.*, Vol. 7, No. 3, Pp. 28–32, 2019.
[5] W. S. Susilo, C. Danuputri, A. P. Thenata, And L. Hakim, "Rancang Bangun Alat Deteksi Gas Beracun Dengan Algoritma Simple Additive Weighting," *J. Sist. Inf.*, Vol. 5, No. 1, Pp. 1–15, 2023.
[6] Y. Wang, B. Wang, And R. Wang, "Current Status Of Detection Technologies For Indoor Hazardous Air Pollutants And Particulate Matter," *Orig. Res.*, Vol. 23, No. 12, Pp. 1–20, 2023.
[7] Z. Zaini And T. H. Alvy, "Design Of Monitoring System For Hazardous Gas And Fire Detection In Building Based On Internet Of Things," *Andalas J. Electr. Electron. Eng. Technol.*, Vol. 1, Pp. 13–20, 2022.
[8] T. Mazhar *Et Al.*, "Quality Of Service (Qos) Performance Analysis In A Traffic Engineering Model For Next-Generation Wireless Sensor Networks," *Symmetry (Basel).*, Vol. 15, No. 2, P. 513, 2023.
[9] S. Kumar And A. Jasuja, "Air Quality Monitoring System Based On Iot Using Raspberry Pi," *Int. Conf. Comput. Commun. Autom.*, Pp. 1341–1346, 2017.
[10] K. S. E. Phala, A. Kumar, And G. P. Hancke, "Air Quality Monitoring System Based On Iso / Iec / Ieee 21451 Standards," Pp. 1–9, 2020.
[11] M. T. Q. Ramadhani And I. P. Imam Purwanto, "Teknologi Internet Of Things Untuk Meningkatkan Mobilitas Penyandang Tunanetra Tanpa Batasan Ruang Dan Waktu," *Komputika J. Sist. Komput.*, Vol. 14, No. 1, Pp. 115–124, 2025, Doi: 10.34010/Komputika.V14i1.14289.
[12] R. Muttaqin, W. Sakti, W. Prayitno, And N. E. Setyaningsih, "Rancang Bangun Sistem Pemantauan Kualitas Udara Berbasis Iot (Internet Of Things) Dengan Sensor Dht11 Dan Sensor Mq135," *J. Pengelolaan Lab. Pendidik.*, Vol. 6, No. 2, Pp. 102–115, 2024.
[13] H. W. Huda And A. Setiabudi, "Lokalisasi Dalam Ruangan Menggunakan Esp-Now Berbasis Wireless Sensor Network Trilateration Dengan Model Free Space Path Loss," *J. Pengemb. Teknol. Inf. Dan Ilmu Komput.*, Vol. 7, No. 6, Pp. 3009–3015, 2023.
[14] S. Ainah, Y. Nur Chusnul Khotimah, A. Maharani, N. Noor Kamala Sari, And V. Handrianus Pranatawijaya, "Implementasi Framework Flutter Untuk Pengembangan Aplikasi Restoran Dengan Penerapan Api Chatgpt," *Jati (Jurnal Mhs. Tek. Inform.*, Vol. 8, No. 3, Pp. 3802–3809, 2024, Doi: 10.36040/Jati.V8i3.9804.
[15] M. N. Laili And S. Sufaidah, "Pendeteksi Asap Berbasis Internet Of Things Mila," *Exact Pap. Compil.*, Vol. 4, No. 4, Pp. 2–7, 2022.
[16] C. L. Aldea, R. Bocu, And R. N. Solca, "Real-Time Monitoring And Management Of Hardware And Software Resources In Heterogeneous Computer Networks Through An Integrated System Architecture," *Symmetry (Basel).*, Vol. 15, No. 6, P. 1134, 2023.