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# Air Filtration System Utilizing Biomimetic Technology and IoT for Air Quality Improvement

Mochamad Rizal Fauzan[1], Silmi Ath Thahirah Al Azhima[2], Resa Pramudita[3], Dadang Lukman Hakim[4], Hanifah Indah Rahmawati[5], Mutiara Nabila Azmi[6], Rafi Rahman Fauzi[7], Maman Somantri[8], Sri Rahayu[9]
[1,7,8] Pendidikan Teknik Elektro, UPI, Bandung, Indonesia
[2,3] Pendidikan Teknik Otomasi Industri dan Robotika, UPI, Bandung, Indonesia
[4] Teknik Elektro, UPI, Bandung, Indonesia
[5,6,9] Pendidikan Teknik Bangunan, UPI, Bandung, Indonesia
[1]rizalfauzan@upi.edu, [2]silmithahirah@upi.edu, [3]resa.pd@upi.edu, [4]dadanglh@upi.edu, [5]hanifahindah08@upi.edu, [6]mutiaranabila08@upi.edu, [7]rafi.zahranf@upi.edu, [8]msomantri@upi.edu, [9]srirahayu@upi.edu

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***Abstract*— The "Hepix" smart air filtration system, developed with biomimetic and Internet of Things (IoT) technology, aims to address the urgent issue of poor indoor air quality, particularly in high-mobility urban areas. This system integrates advanced sensors (MQ135 and BME680) and biomimetic filtration inspired by leaf stomata to monitor and filter air pollutants. Tested across three locations—Cilame, Jatinangor, and Cibiru—the system achieved an approximate 24.4% reduction in pollutant levels, as well as stable control of humidity and air pressure. Real-time data is continuously monitored through a mobile and web interface, supported by Google Assistant integration for voice commands. The results demonstrate that "Hepix" effectively improves air quality, offering a practical solution for healthier indoor environments in urban areas.**

***Index Terms*— Air filtration; biomimetic technology; Internet of Things; indoor air quality.**

## I. Introduction

Urban air quality has become an increasingly urgent environmental issue. The rising emissions from motor vehicles, industries, and other human activities have led to a significant decline in air quality. According to an IQAir report in July 2024, Indonesia ranks third out of 116 countries with the highest levels of air pollution in the world, with most of this pollution concentrated in urban areas with dense industrial activities [1][2]. The impact of this air pollution is not limited to the environment but also has serious health consequences, including an increased risk of chronic respiratory diseases such as asthma, bronchitis, and even lung cancer [3][4].

Amid this urgency, the development of technologies to improve indoor air quality has become crucial. Several innovations have been developed to filter and enhance air quality, such as the "Smart Air Purifier" system [5], which uses an MQ135 sensor and Arduino Uno to monitor and filter air particles. However, this study revealed some limitations, such as the device's inability to identify the type of pollutants being filtered and a design that is less portable and practical for everyday use [6].

Another study about developed an indoor air quality monitoring system using a microcontroller and an Android application [7][8]. Although this device provides a good monitoring solution, limitations such as the Bluetooth signal range of only about 10 meters and the lack of integration with AC power make this system less optimal for wider urban use [9][10]. This indicates a need for more advanced and comprehensive solutions to address indoor air quality challenges [11].

To address these limitations, this research offers the development of a smart air filtration system based on biomimetic and Internet of Things (IoT) technology, named "Hepix." This system not only filters the air but also monitors air quality in real time through the integration of advanced sensors such as the MQ135 and BME680 [12][13]. The biomimetic technology employed mimics the natural mechanism of leaf stomata, which effectively manages gas exchange in plants, to be applied in air filtration. IoT integration allows continuous air quality monitoring and control through a smartphone-based application, enabling users to access air quality information and operate the system remotely [14][15].

Furthermore, the system is integrated with Google Assistant, allowing users to activate or deactivate the system through voice commands. This feature provides added convenience and ease of use in daily life, especially for those living in areas with varying air

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quality [16]. This study aims to develop and test the effectiveness of a smart air filtration system based on biomimetic and IoT technology in improving indoor air quality in urban environments. Through this approach, it is expected to provide a more effective and efficient solution to indoor air pollution problems, while also contributing new insights into the application of biomimetic and IoT technology for environmental health [17].

## II. METHOD

This section describes the development process of the "Hepix" air filtration system, covering system architecture, hardware design, and software design. Each element is designed to ensure the system can effectively monitor and improve indoor air quality [18].

### A. System Architecture and Flowchart

The system architecture of "Hepix" illustrates the structure and interaction between key components, such as advanced sensors and IoT integration, enabling real-time air quality monitoring and filtration. The architecture diagram Fig 1 shows the main elements, including the MQ135 and BME680 sensors, microcontroller, and IoT framework, which allow for remote monitoring and control.

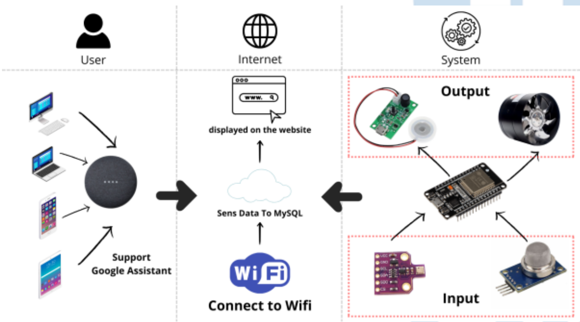



Fig. 1. Architecture system design

The flowchart Fig 2 outlines the operational flow from initial air quality detection, through filtration, to real-time data updates on the user interface. This diagram demonstrates the logical sequence of data collection, processing, and user notifications, showing how each component works together to improve air quality.

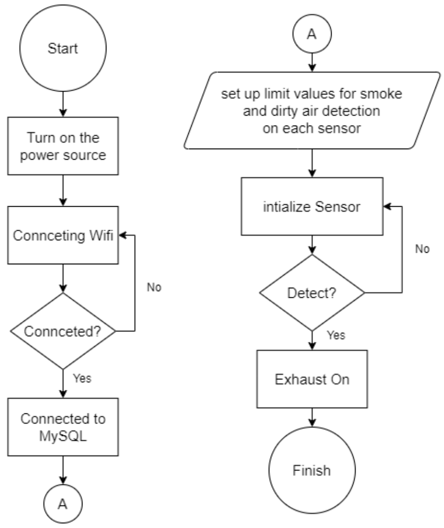



Fig. 2. Flowchart system

### B. Hardware Design

The hardware design of the "Hepix" system includes the detailed specifications of the physical components necessary for effective air filtration and air quality monitoring. This includes sensors like MQ135 and BME680, essential for measuring pollutants and environmental parameters. Fig 3 provides the schematic design, illustrating the circuit connections and how each component is integrated to function cohesively within the system.

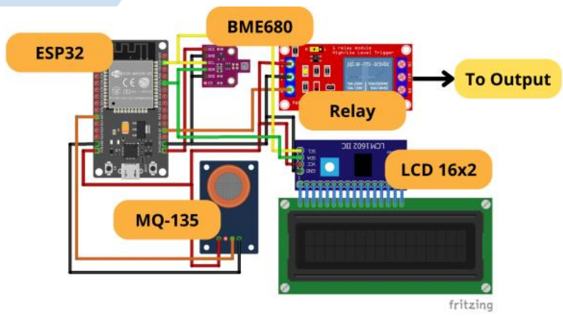



Fig. 3. Schematic Design

Additionally, Fig 4 shows the 3D product design, highlighting the physical layout and structural arrangement to ensure the device is both portable and user-friendlyand in Fig 5 is the realization of the tool. This design approach aims to enhance the practical usability of the system in various indoor environments, facilitating easier deployment and maintenance, and product.

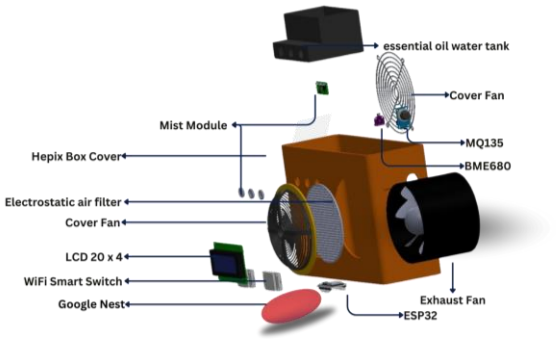



Fig. 4. Design 3D Product


Fig. 5. Realization Product

## C. Software Design

The software design incorporates programming for data acquisition, processing, and communication with the user interface. Fig 6 presents the software system architecture as implemented on the web interface, displaying the data flow from sensors to the MySQL database and further to the user application. This design enables seamless interaction between the device and the IoT framework, allowing for continuous air quality monitoring and control through the web interface.

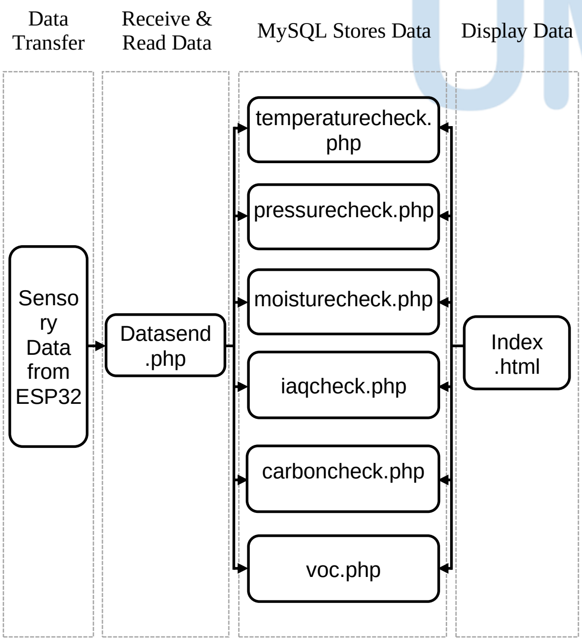
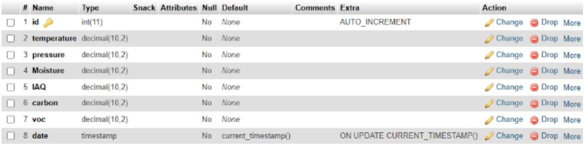



Fig. 6. Architecture software system design on website

Further details on data management are shown in Fig 6, which illustrates the MySQL database structure. This database stores real-time air quality data, which can be accessed and displayed through the user application. The integration of Google Assistant also provides voice-command functionality, offering users a convenient and hands-free way to interact with the system.



| # | Name | Type | Snack | Attributes | Null | Default | Comments | Extra | Action |
|---|---|---|---|---|---|---|---|---|---|
| 1 | id | int(11) | | | No | None | | AUTO_INCREMENT | Change Drop More |
| 2 | temperature | decimal(10,2) | | | No | None | | | Change Drop More |
| 3 | pressure | decimal(10,2) | | | No | None | | | Change Drop More |
| 4 | Moisture | decimal(10,2) | | | No | None | | | Change Drop More |
| 5 | IAQ | decimal(10,2) | | | No | None | | | Change Drop More |
| 6 | carbon | decimal(10,2) | | | No | None | | | Change Drop More |
| 7 | voc | decimal(10,2) | | | No | None | | | Change Drop More |
| 8 | date | timestamp | | | No | current_timestamp() | | ON UPDATE CURRENT_TIMESTAMP() | Change Drop More |

Fig. 7. MySQL Data

# III. Testing And Result

This section presents the testing process and results of the "Hepix" air filtration system, conducted in three different regions: Cilame, Jatinangor, and Cibiru. Each location was selected to represent distinct environmental conditions, providing a comprehensive evaluation of the system’s effectiveness in diverse indoor settings. The tests focused on key metrics, including functional testing, humidity, air quality index, air pressure, and a comparative analysis of pollutant concentration (PPM) before and after using the device.

The tests were conducted in a living room with a size of 15 m² (or 45 m³), which was selected as the optimal room size for the air filtration system. This room size represents a typical indoor environment in residential areas, providing a controlled setting that mirrors common living conditions. The living room was chosen specifically because it is closest to the external environment, allowing for a more accurate comparison between indoor air quality and outdoor conditions. During the tests, the room was maintained under typical residential conditioning scenarios, with the air conditioning and ventilation systems operating at standard settings, ensuring that the results reflect realistic usage conditions.

## A. Functional Testing Results

The initial functional testing was conducted to ensure that each component of the "Hepix" system operated as intended. This included testing sensor accuracy, device responsiveness, and IoT connectivity. Table I summarizes the functionality test results, detailing the performance and reliability of each system component under various conditions.

TABLE I. Functionality Testing

| Component | Functionality | Result | Remarks |
|---|---|---|---|
| MQ135 Sensor | Detect air pollutants (CO2, NH3) | Pass | Responsive to pollutant levels |

| | | | |
|---|---|---|---|
| BME680 Sensor | Measure temperature and humidity | Pass | Stable measurements |
| Microcontroller | Data processing and sensor control | Pass | No delay in data processing |
| IoT Module | Connects to mobile app and website | Pass | Consistent connection with app and website |
| Biomimetic-Based Air Filtration | Filter out indoor pollutants | Pass | Effective reduction in PPM levels |
| Google Assistant | Voice activation | Pass | Commands executed accurately |
| Power Supply | Continuous power delivery | Pass | Suitable for long-term operation |

### B. Humidity

The humidity measurements in Jatinangor, Cibiru, and Cilame show varying average levels, with Jatinangor at 80.1%, Cibiru at 77.3%, and Cilame at 73.1%. The graph illustrates daily humidity fluctuations across these locations, highlighting the "Hepix" system's ability to adapt to different environmental conditions in maintaining balanced indoor humidity show in Fig 8.

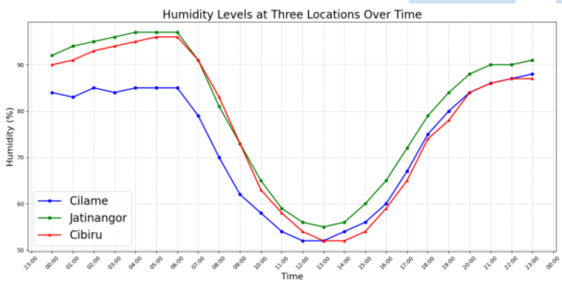



Fig. 8. Humidty Graph

### C. Air Quality Index (AQI)

The AQI measurements across Jatinangor, Cibiru, and Cilame show average values of 67.5%, 68.4%, and 68.7%, respectively. The graph illustrates variations in AQI levels throughout the day, reflecting fluctuations in air quality across these locations. This data helps assess the "Hepix" system's capability to respond to changes in air quality and improve indoor environments effectively, as shown in Fig 9.

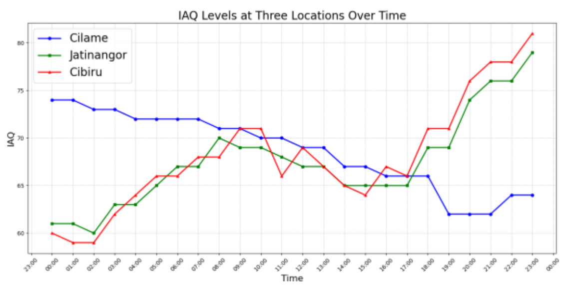



Fig. 9. AQI Graph

### D. Air Pressure

Air pressure measurements across Jatinangor, Cibiru, and Cilame show average values of 1003.07 hPa, 1013.98 hPa, and 929.28 hPa, respectively. The graph illustrates the stability of air pressure over time at each location, indicating minor fluctuations throughout the day. This data, as shown in Fig 10, helps evaluate the "Hepix" system's ability to operate effectively under varying environmental pressures.

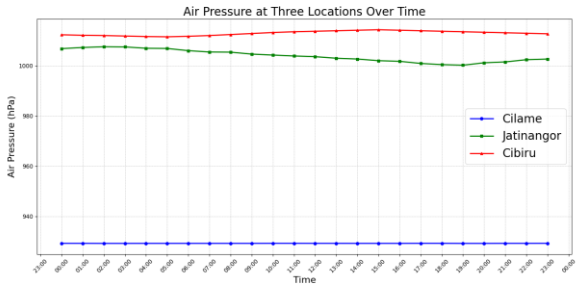



Fig. 10. Air Pressure Graph

### E. Comparative PPM Graph: Before and After Using the Device

A comparative analysis of pollutant concentration (PPM) levels on July 2 and July 3 highlights the system's effectiveness in reducing indoor air pollution. The highest PPM recorded on July 2 was 742, which decreased to 561 on July 3, a reduction of approximately 24.4%. This reduction illustrates the "Hepix" system's capability to significantly lower pollutant levels, providing a healthier indoor environment by filtering airborne contaminants over time, as shown in Fig 11.

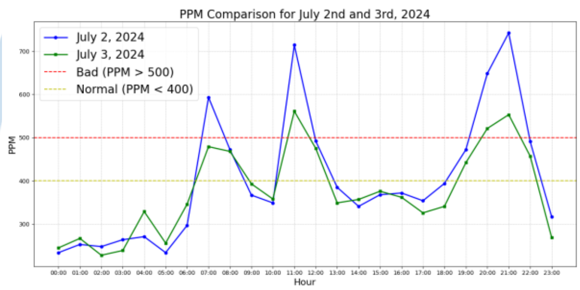



Fig. 11. Comparative PPM Graph

### F. Software Result


Fig. 12. Hepix system dashboard

The "Hepix" system's software dashboard, as shown in Fig 12, provides real-time monitoring of key environmental parameters, including temperature, pressure, humidity, and pollutant concentrations (e.g., $CO_2$, CO, and VOCs) in PPM. This web-based interface enables users to track indoor air quality metrics efficiently, allowing for timely responses to changing conditions. The intuitive design and clear display ensure that users can easily interpret data and make informed decisions about their indoor environment.

## IV. Conclusion

The development and testing of the "Hepix" smart air filtration system, which integrates biomimetic and IoT technology, highlight its effectiveness in enhancing indoor air quality across varied environmental conditions. Conducted in three locations with high mobility and diverse air quality challenges Cilame, Jatinangor, and Cibiru the study demonstrated the system's adaptability and robustness in maintaining healthy indoor environments. The "Hepix" system achieved a notable pollutant concentration reduction of approximately 24.4%, showcasing its ability to significantly improve air quality. Functional tests confirmed the reliability of all components, including pollutant and environmental sensors, IoT connectivity for real-time monitoring, and Google Assistant integration for hands-free operation. These results position the "Hepix" system as a promising solution to address urban indoor air pollution, offering practical applications that support healthier, safer living spaces through continuous air quality monitoring and filtration.

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