DEVELOPMENT OF AIR QUALITY MONITORING DEVICE (AQMD) WITH INTERNET OF THINGS (IOT) APPLICATION

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ABSTRACT

A prototype Air Quality Monitoring Device (AQMD) has been developed to monitor the concentrations of major air pollutant gases. The system uses inexpensive air-quality monitoring nodes that incorporate a semiconductor gas sensor and a wireless module. This system uses semiconductor sensors to determine the concentrations of several gases, including PM 2.5, CO, SO_2, and NO_2. The sensors can collect data on a variety of environmental variables and transmit it to the Arduino Mega 3560 R3 serving as a base station. Additionally, a temperature and humidity sensor was added to the prototype. Sensor data is visualised using the Blynk application on a mobile device. The intended study's defining characteristic is the establishment of a low-cost infrastructure for data collecting. As a result, it is believed that this integrated strategy might open the way for other initiative-based approaches to resolving issues, particularly in the industrial sector.

Keywords: Environment Quality, Air Pollution, Gas Detection, Arduino Sensor.

1. INTRODUCTION

Environmental pollution is the adverse transformation of our environment due to man's actions, either directly or indirectly, through changes in the energy pattern, radiation levels, chemical and physical constitution, and abundance of species. As noted by [1] [2, environmental pollution is a worldwide issue that affects both wealthy and developing countries, attracting human attention due to its dire long-term repercussions. Pollution-induced degradation of the environment is manifested by the loss of vegetation and biological variety, the accumulation of hazardous chemicals in the ambient atmosphere and food grains, and the rising risk of 15 environmental mishaps and threats to life support systems. Pollution is seen differently by various people, although it is widely acknowledged to be the outcome of the urban-industrial and technological revolutions and the greedy and fast exploitation of natural resources. Furthermore, the increased pace of matter and energy exchange and the ever-increasing industrial wastes, urban effluents, and consumer products contribute to pollution [2]. As a result of air pollution and changes in climatic equalisation, concern about medical concerns has spread worldwide [3][4].

In light of these critical issues, residents of the industrial town of Pasir Gudang have urged specialists to conduct more frequent monitoring of the territory's air quality and to update an early warning system in light of the regular occurrences of children experiencing breathing difficulties and regurgitating due to contamination. Given that Pasir Gudang is a contemporary zone, the

administration must have detectors in place to detect any chemical pollution seen throughout [5]. Carbon monoxide is produced in various ways, including automotive emissions, home or building heating, forest fires, vegetative growth, and the chemical decomposition of methane [6]. In Malaysia, forest fires, industrial pollutants, and motor vehicles contribute to changes in the atmosphere [7]. Additionally, automobile growth accounts for 75% of total emissions in Malaysia [8]. [9]. Global warming is one of the consequences of environmental change. The primary source of unnatural weather change is ozone-depleting chemicals due to mechanical activity, consumption, and automobile traffic. Malaysia is in danger of global warming, which manifests itself in various ways [10]. According to [11], Pasir Gudang's poor air quality results from its proximity to various ventures, including transportation and coordination, shipbuilding, petrochemicals and other large enterprises, and oil palm stockpiling and conveyance.

The Air Pollution Index (API) is a daily air quality indicator. API typically contains the most harmful air contaminants to human health. It educates the public about air pollution in a comprehensible manner. According to ([12], Malaysia's government established the Malaysian Air Quality Index (MAQI), which is based on the US Environmental Protection Agency's Pollutant Standard Index (PSI) (EPA). Carbon monoxide (CO), nitrogen dioxide (NO_2), sulphur dioxide (SO_2), ozone (O_3), and suspended particulate matter smaller than 2.5 microns in size are all included in Malaysia's API (PM2.5) [13]. The API rating system used in Malaysia is depicted in Table 1.

Table 1: API rating system adopted in Malaysia.

API	Air Pollution Level
0-50	**Good**
51-100	**Moderate**
101-200	**Unhealthy**
201-300	**Very Unhealthy**
301-500	**Hazardous**
500+	**Emergency**

2. METHODOLOGY

This research has two aims. The initial aim is to create a prototype of an alternative Air Quality Monitoring Device (AQMD) model using the Internet of Things (IoT) as the monitoring foundation. Secondly, to assess the AQMD's performance in monitoring the air quality in the study region. The research process is depicted in Figure 1. This project utilises various hardware and software components, including the MQ135 sensor, the PMS5003 sensor, the DHT22 sensor, the Arduino Mega 2560 board, the ESP8266 WiFi module, the Blynk application, and the Arduino Ide in developing the prototype. After developing and building the prototype, the project design may be created to ensure that the hardware is constructed and connected correctly according to its pin. Additionally, the project diagram was created to aid in the simple understanding of the link between the hardware and software.

This project was developed using the Rapid Application Development (RAD) approach. The RAD approach enables rapid prototyping, which speeds up the planning process and conserves resources. Additionally, it is the ideal model to utilise while improvising the prototype since it was created prior to completing the final product. The creation of an Air Quality Monitoring Device (AQMD) project entails a great deal of repetition. Due to the proliferation of configuration, software, and equipment on the market today, pre-testing configuration must be performed continuously to verify the hardware and software's dependability. As a result, the RAD model is the most appropriate model to use for this project. The quick application development cycle utilised for this project is depicted in Figure 2, while the prototype isometric design is illustrated in Figure 3.

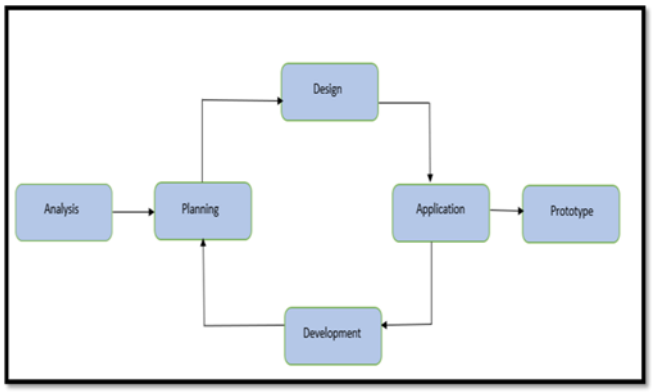
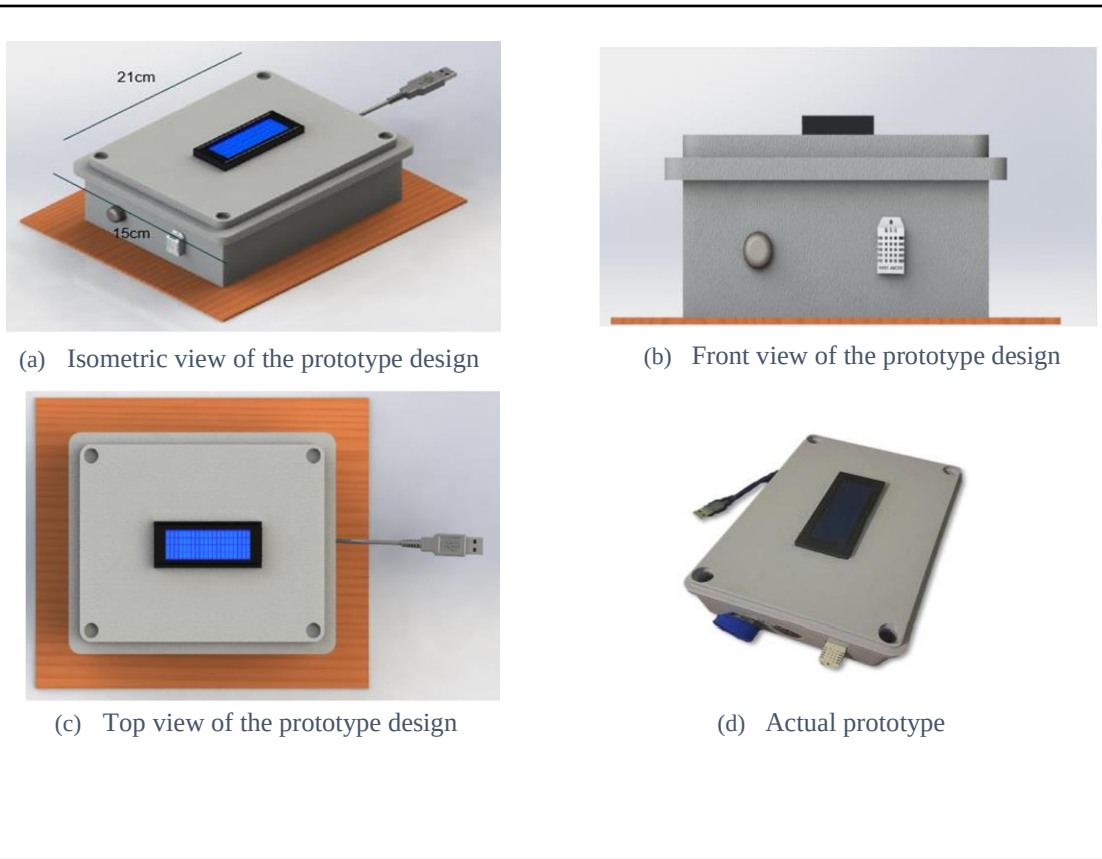


Figure 2: Rapid action development cycle.



(a) Isometric view of the prototype design

(b) Front view of the prototype design

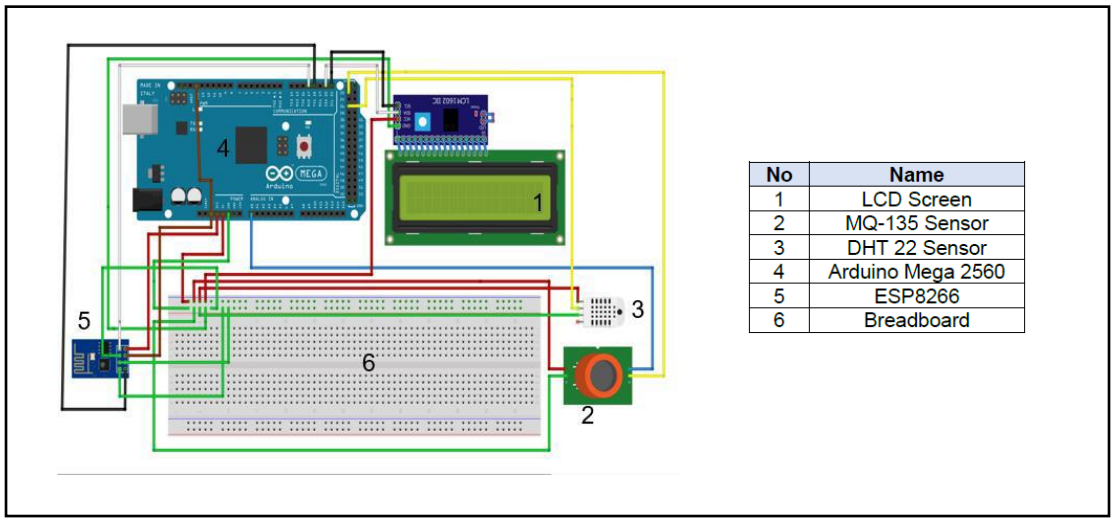
(c) Top view of the prototype design

(d) Actual prototype

Figure 3: Illustration of the prototype model.

Before moving on to the following phase, it is critical to complete the electrical design. To begin, the researcher must create an electrical design using the Fritzing programme on a computer. For this project, the most critical link was the one between sensors and other equipment. Incorrect

sensor connection can result in sensor damage, inability to operate, and short circuit. All connections are made using the pin configuration of the ESP8266 WiFi Module, the DHT22 Humidity and Temperature Sensor, the MQ135 Air Quality Sensor, the Arduino Mega 2560 R3, and the Arduino LCD 20x4. The electrical connection of the components is depicted in Figure 4.



No	Name
1	LCD Screen
2	MQ-135 Sensor
3	DHT 22 Sensor
4	Arduino Mega 2560
5	ESP8266
6	Breadboard

Figure 4: Illustration of electrical connections of the components.

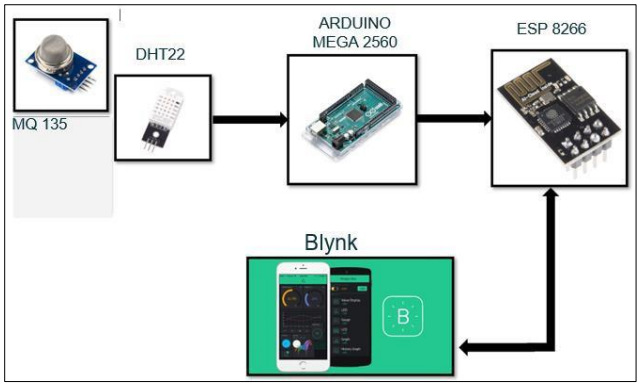


Figure 5: Prototype workflow.

Figure 5 depicts an IoT-enabled AQMD prototype process. The researcher creates the project diagram to simplify and aid in comprehending the hardware and software processes. The MQ135 and DHT22 sensors' analogue and digital values are gathered and sent to the Arduino Mega board. The Arduino Mega board then reads the analogue and digital values from the MQ135 and DHT22 sensors and transforms them to part per million (ppm), humidity in percentage (%), and temperature values (^{o}C). Then, the Arduino Mega transmits to the ESP8266 the air quality, temperature, and humidity values. It connects through WiFi and sends the value to the Blynk application. Finally, the user may monitor the value using the Blynk application on their mobile device, as seen in Figure 6.

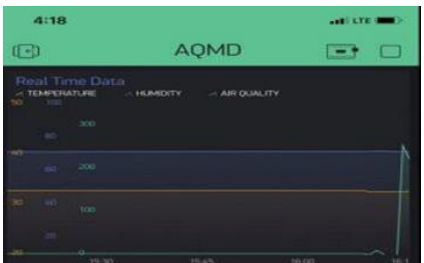


Figure 6: Display on Blynk application.

3. RESULTS AND DISCUSSION

Three factors are being analysed: air quality in parts per million units (ppm), the temperature in degrees Celsius (°C), and relative humidity in percentage (%). The data collected from the parameter were displayed in the form of a table and graph. It includes readings of the air quality (ppm) as determined by the MQ-135 sensor, the temperature (°C) as determined by the DHT-22 sensor, and the humidity (%) as determined by the DHT-22 sensor in real-time in minutes and hours. All air quality, temperature, and humidity measurements are monitored and displayed via the BLYNK smartphone application. The data in Table 1 and Table 2 were collected and acquired by the experimental on the study location, which was chosen within the complex of the UniKL MITEC campus, on two separate days. While real-time data in Figure 7 and Figure 8 were also collected in the same day.

Table 2: Data collection on the first session (Monday).

Time	Air Quality (ppm)	Temperature (°C)	Humidity (%)
9:32:50 AM	39 PPM	29.6 °C	83.75%
9:47:43 AM	45 PPM	29.6 °C	83.75%
10:05:13 AM	51 PPM	29.9 °C	83.75%
10:19:26 AM	45 PPM	30.2 °C	83.75%
10:35:14 AM	47 PPM	30.2 °C	83.75%
16:19:51 PM	55 PPM	32.6 °C	70.90%
16:36:04 PM	49 PPM	32.6 °C	70.90%
16:48:45 PM	57 PPM	32.6 °C	70.90%
16:57:23 PM	59 PPM	32.6 °C	70.90%
17:15:55 PM	57 PPM	32.3 °C	70.90%

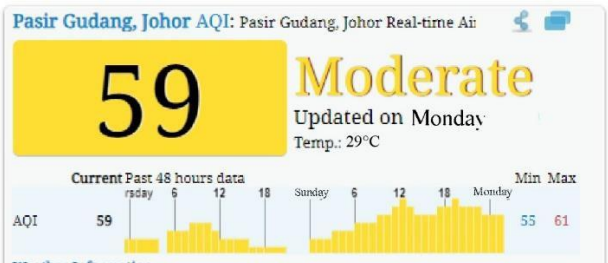


Figure 7: Malaysian Real-Time Air Quality Website on Monday.
(https://aqicn.org/city/malaysia/johor/pasir-gudang/).

Table 3: Data Comparison between AQMD and real-time values on the first session (Monday)

Parameter	Real-Time Air Quality Index (AQI) Data	AQMD Value (Average)
AQI (ppm)	**59**	**50.4**
Temperature (°C)	**25 - 33**	**31.22**
Humidity (%)	**59 - 94**	**77.33**

According to the findings and data gathered during the first session on weekdays (Monday), the morning air quality level was 39 ppm and the evening level was 57 ppm. The increase in the value of the air quality parameter is due to commonplace activities (such as transportation) near the testing location. Additionally, the research area is close to the industrial district of Pasir Gudang. Comparing the data gathered by AQMD to the real-time AQI for Pasir Gudang on the same day, as given in Table 2, demonstrates that the AQMD prototype operates near real-time values. The second session's results are summarised in Table 4, Table 5, and Figure 8. Again, the AQMD is doing admirably. Each parameter's recorded value is close to the real-time value obtained from the aqins.org website.

Table 4: Data collection on the second session (Saturday).

Time	Air Quality (ppm)	Temperature (°C)	Humidity (%)
9:17:33 AM	29 PPM	26.4 °C	89.06%
9:35:55 AM	42 PPM	26.4 °C	89.06%
9:56:13 AM	37 PPM	26.5 °C	89.06%
10:12:21 AM	40 PPM	26.5 °C	89.06%
10:27:54 AM	35 PPM	26.5 °C	89.06%
16:30:11 PM	39 PPM	29.3 °C	81.03%
16:46:42 PM	45 PPM	29.3 °C	81.03%
16:55:22 PM	40 PPM	29.3 °C	81.03%
17:13:50 PM	44 PPM	29.2 °C	81.03%
17:27:13 PM	43 PPM	29.2 °C	81.03%

Figure 8: Malaysian Real-Time Air Quality Website on Saturday.
(https://aqicn.org/city/malaysia/johor/pasir-gudang/).

Table 5: Data Comparison between AQMD and real-time values on the second session (Saturday).

Parameter	Real-Time Air Quality Index (AQI) Data	AQMD Value (Average)
AQI (ppm)	**45**	**50.4**
Temperature (^{o}C)	**25 - 33**	**27.86**
Humidity (%)	**52 - 94**	**85.05**

As a result, the AQMD display value may be used to determine the extent of air pollution at a particular place. As illustrated in Table 6, reference guidelines on air pollution levels and their associated health consequences can be used to monitor conditions and plan for necessary action when pollution levels reach specific levels to mitigate any health consequences that could jeopardise the human body or health. The present prototype is entirely reliant on grid electricity. As a result, the areas where the prototype may be installed are limited.

Table 6: API in Malaysia and Health Implications [13] [14].

AQI	AIR POLLUTION LEVEL	HEALTH IMPLICATIONS	CAUTIONARY STATEMENT (FOR PM2.5) (AQINS)	HEALTH ADVICE (APIMS)
0 -50	Good	Air quality is considered satisfactory, and air pollution poses little or no risk.	None	No restriction for outdoor activities to the public. Maintain healthy lifestyle.
51 -100	Moderate	Air quality is acceptable; however, for some pollutants there may be a moderate health concern for a very small number of people who are unusually sensitive to air pollution.	Active children and adults, and people with respiratory disease, such as asthma, should limit prolonged outdoor exertion.	No restriction for outdoor activities to the public. Maintain healthy lifestyle.
101-200	Unhealthy (for Sensitive Groups)	Members of sensitive groups may experience health effects. The general public is not likely to be affected. Worsen the health condition for elderly, pregnant woman, children and people who is with heart and lung complications.	Active children and adults, and people with respiratory disease, such as asthma, should limit prolonged outdoor exertion.	Limited outdoor activities for the high risk people.
201-300	Very Unhealthy	Health warnings of emergency conditions. The entire population is more likely to be affected.	Active children and adults, and people with respiratory disease, such as asthma, should avoid all outdoor exertion; everyone else, especially children, should limit outdoor exertion.	Old and high risk people are advised to stay indoor and reduce physical activities. People with health complications are advised to see doctor.
300+	Hazardous	Health alert: everyone may experience more serious health effects	Everyone should avoid all outdoor exertion	Old and high risk people are prohibited for outdoor activities. Public are advised to prevent from outdoor activities.
500+	Emergency	Hazardous to high risk people and public health.	-	Public are advised to follow orders from National Security Council and always follow the announcement in mass media

4. CONCLUSION

This project focused on building a low-cost prototype for air quality monitoring that may be used to provide early warning to the public. The prototype is intended to aid in safeguarding a facility's safety and health conditions. Although it was developed using low-cost components, the devices' measurements are within an acceptable range compared to the industrial equipment used to assess air quality. The prototype is being installed as a precautionary measure and preparedness for an unanticipated future risk or disaster that might cause harm to the people and population in the vicinity of the established area. The researcher's objectives are accomplished based on the experimental findings and comparison to real-time data. It is advised for future studies that the prototype be equipped with high-quality sensors to ensure the prototype's endurance against adverse weather conditions. Additionally, the prototype's components shall be modified with a backup energy supply or a link to a photovoltaic system to power the system. Thus, the prototype may be put in any open site for an extended length of time and can enhance monitoring duration without relying on grid power.

REFERENCES

[1] Rai, P. K. (2016). Biomagnetic Monitoring of Particulate Matter. Elsevier Science.

[2] Jiang, B., Sun, Z., & Liu, M. (2010). China's energy development strategy under the low-carbon economy. Energy, 35(11), 4257-4264.

[3] Chen, C., Chen, B., Wang, B., Huang, C., Zhao, J., Dai, Y., & Kan, H. (2007). Low-carbon energy policy and ambient air pollution in Shanghai, China: a health-based economic assessment. Science of the Total Environment, 373(1), 13-21.

[4] Morra, P., Bagli, S., & Spadoni, G. (2006). The analysis of human health risk with a detailed procedure operating in a GIS environment. Environment International, 32(4), 444-454.

[5] Hammim, R. (2019). Pasir Gudang air will be monitored by new auto gas detectors. News Straits Times. https://www.nst.com.my/news/nation/2019/11/540107/pasir-gudang-air-will-be-monitored-new-auto-gas-detectors

[6] Daly, A., & Zannetti, P. (2007). Air pollution modeling–An overview. Ambient air pollution, 15-28.

[7] Aghamohammadi, N., & Isahak, M. (2018). Climate change and air pollution in Malaysia. In Climate Change and Air Pollution (pp. 241-254). Springer, Cham.

[8] Mustafa, M., Kader, S. Z. A. K., & Sufian, A. (2012). Coping with climate change through air pollution control: some legal initiatives from Malaysia. In 2012 International Conference on Environment, Energy and Biotechnology (Vol. 33, pp. 101-105).

[9] Brohi, S. N., Pillai, T. R., Asirvatham, D., Ludlow, D., & Bushell, J. (2018). Towards smart cities development: a study of public transport system and traffic-related air pollutants in Malaysia. In IOP conference series: earth and environmental science (Vol. 167, No. 1, p. 012015). IOP Publishing.

[10] Ahmad, N. N. N., & Hossain, D. M. (2015). Climate change and global warming discourses and disclosures in the corporate annual reports: A study on the Malaysian companies. Procedia-social and behavioral sciences, 172, 246-253.

[11] Yap, C. K., Peng, S. H. T., & Leow, C. S. (2019). Contamination in Pasir Gudang Area, Peninsular Malaysia: What can we learn from Kim Kim River chemical waste contamination?. Journal of Humanities and Education Development (JHED), 1(2), 84-87.

[12] Afroz, R., Hassan, M. N., & Ibrahim, N. A. (2003). Review of air pollution and health impacts in Malaysia. Environmental research, 92(2), 71-77.

[13] Air Pollutant Index of Malaysia User Manual (2019), Ministry of Environment And Water's. Retrieved from http://apims.doe.gov.my/public_v2/pdf/User_Manual_APIMS_v01.pdf

[14] Air Quality Historical Data (2021). Pasir Gudang, Johor Air Pollution: Real-time Air Quality Index (AQI). Retrieved from https://aqicn.org/city/malaysia/johor/pasir-gudang/