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Research paper

Low-Cost Real-Time Mobile Air-Quality Monitoring System (AQMS)

Iman Amanina Binti Asim[1]*, Asma' Murizah Binti Kamarudin[1], Munirah Onn[2], Shakira Azeehan Azli[1], Aznilinda Zainuddin[1], Norlina Mohd Zain[1], Khairul Kamarudin Hasan[1].

[1] Faculty of Electrical Engineering, Universiti Teknologi MARA, Cawangan Johor, Kampus Pasir Gudang,81750 Masai, Johor, Malaysia.
[2]Faculty of Applied Sciences, Universiti Teknologi MARA, Cawangan Johor, Kampus Pasir Gudang,81750 Masai, Johor, Malaysia.
**Corresponding author E-mail: imanasim91@gmail.com*

Abstract

Air quality is one of the dominant health and environmental interest issues in the world thus it is important to monitor air quality at surrounding area especially in big cities and urban areas. This paper explains the development of a reliable and cost-effective air quality monitoring system (AQMS) that can measure the air quality at indoor and outdoor area and to alert the user of the hazardous air quality index (AQI) level through an alarm system upon detection. By using Arduino platform and various sensors along with a flat-panel liquid-crystal display (LCD) and Bluetooth module, the system detects the level of the hazard gases, temperature and humidity of the area. The AQMS is a portable air quality index (AQI) acquisition device that is simple to carry and provide real-time measurement on the LCD. It is a user-friendly device and handy to operate. The AQMS gives the public an opportunity to monitor the air quality personally and helps to bring awareness on the real-time air quality around them and improve the air quality.

Keywords: *air pollution, air quality index, Arduino, humidity sensor, air quality.*

1. Introduction

Poor air quality contributed by open burning, forest fires, vehicles exhaust, air pollutions, industrial sources and many more is a serious matter that rises concerns among the urban society. The particles in the polluted air are harmful as they penetrate and contaminate our internal organs that can lead to critical diseases and death cases. Air pollution is reported as a significant risk factor for human health by World Health Organization (WHO) [1]. Based on the data recorded by WHO in 2012, around 6,251 people had died from diseases due to air pollution and it is believed that more fatalities have been recorded when the death caused by indoor air pollution is included [2].

Apart from that, people who suffer from asthma, allergic to dust and have weak antibody are easily affected by the hazardous particles in the air. Greater numbers of air pollution fatality are attributed to cardiovascular diseases like ischemic heart disease, strokes and chronic obstructive pulmonary disease (COPD). Moreover, new research has proven a link between air pollution and marked up mental illness in children. The results show that higher concentrations of air pollution mainly from traffic may enhance psychiatric disorders among babies and youngsters [3].

Collecting samples on site and then transporting them to the laboratory for analysis is a classic environmental sampling methods. Recently, air pollution is currently monitored by environmental or government authorities using static monitoring stations, which are appareled with instruments for surveying regulative pollutants. The air pollutant analyzers are relatively heavy, big and a significant amount of resources are also required to routinely maintain and calibrate them. These methods can be time consuming and very costly and ongoing research has focused on the development of sensors that can take over traditional sampling practice to monitor contaminants in the environment [4, 5].

The increasing trend of the global urbanization results in air-pollutants concentrated in urban areas and megacities [1]. To give sufficient health and environmental protection, an effective air quality monitoring system is a required device. It is imperative that the device is easy to carry, cheap, reliable and simple to be used. Moreover, this device should be highly sensitive to minor concentrations of gaseous air contamination such as carbon monoxide and hydrogen which prevails in cigarette smoke. The present trend for air pollution monitoring and alarm systems development is to enhance the sensitivity and to scale down the response time, especially at low air contaminants concentrations [6].

An air quality index (AQI) is an index practiced by government agencies for announcing daily air quality to the public. As AQI increases, public will probably have to experience increasingly serious adverse health effects. AQI readings below 50 and above 100 are considered as good and dangerous respectively. AQI within 51 and 100 is acceptable but pollution in these parameters may offer a moderate health concern for few people. Person who is uncommonly sensitive to ozone or particle pollution may struggle respiratory symptoms. To monitor air quality at people surrounding area, real time indoor and outdoor Air Quality Monitoring System is proposed [7,8].

Malaysia is one of the countries that incorporates the air pollution monitoring as the initial strategy in the pollution prohibition program. Because of this, the government has set up Malaysian air pollution index, air quality guidelines and haze action plan to improve air quality. The review of air pollution in Malaysia is based on the reports of the air quality monitoring in several large cities in Malaysia. The air pollutant contained in Malaysia's AQI are ozone (O3), nitrogen dioxide (NO2), sulphur dioxide (SO2), carbon monoxide (CO) and suspended particulate matter lower than 10 microns in size (PM10). Another pollutant such as SO, CO2, OX and Pb are also been monitored in a few big cities. The air pollution comes primarily from industrial emissions, land transportation, and open burning sources. Moreover, industrial waste such as unreacted gas could also affect the air quality index primarily in the place surrounded by industrial area. [9, 10].

AQI number is crucial for all citizens to reduce outdoor activities because a high air pollution level shows a low air quality to people. After all, the current AQI monitoring systems are commonly big in size and the cost is expensive [10]. In order to provide people with real time level of AQI value at their area, this work has been proposed, which is a small hence portable and relatively cheap as it is based on Arduino microcontroller.

Nowadays, sensors are used in every object and have become a part of the daily smart life. The development is to differentiate events and changes in its environment and then complement it with a corresponding output. Sensors can be categorized as transducers as they quantify changes in their environment through various types of output, typically electrical or optical signals [11]. Semiconductor sensors detect gases by a chemical reaction that takes place when the gas comes in direct contact with the sensor. The change in resistance is issued to measure the gas concentration. MQ-135 is a stable semiconductor gas sensor which has good sensitivity to harmful gases in wide range area [12]. MQ-135 is widely used in air quality control equipment. This low-cost AQMS sparks from the study of the increasing rate of air pollution. This work is initiated to measure the quality of air and to collect the data using MQ-135 sensor. Besides, it is also equipped with digital humidity and temperature composite sensor, DHT11.

This work aims to design a prototype that can sense the air quality indoor or outdoor area and to alert the user of the hazardous air upon sensing it and create awareness of air pollution.

2. System Development

In this work, the AQMS main components are the air quality sensor, model MQ-135, temperature and humidity sensor, model DHT11 and the microcontroller Arduino Uno. Four (4) light-emitting diodes (LED) are being used as an indicator of the air quality level. Buzzers are included to function as an alarm system. LCD is used as the display panel to display the reading by both sensors. The MQ-135 can detect Ammonia (NH3), nitrogen oxides (NOX), alcohol, benzene, smoke particles and the greenhouse gas, carbon dioxide (CO2). It operates accurately at an area without an air mover, with high sensitivity and fast response. The MQ-135 uses a micro aluminum oxide (Al2O3) ceramic tube. Its sensing layer is made of stannic oxide (SnO2), due to the characteristic of the SnO2 that has higher resistance in the clear air, its resistance will increase as the air sensed are different compared to the clean air. This makes it suitable to be the main material to operate the air quality sensor. Fig. 1 shows the (Rs/Ro) versus part per million (ppm) graph, which is used to measure the ppm value, as shown in the MQ-135 datasheet [12].

The value read by the sensor is a transformation of the analogue values (0-1023) to its respective output voltage values (V_{OUT}) (0-5V) with: V_{OUT} = (Analog Value * 5) / 1023 [15]. The data collected are converted in an individual AQI and being compared to the regulated Pollution Standard Level using the equation (1). The Pollution Standard Level in Malaysia, from the Malaysian Department of the Environment (DoE) are shown in Table 1.

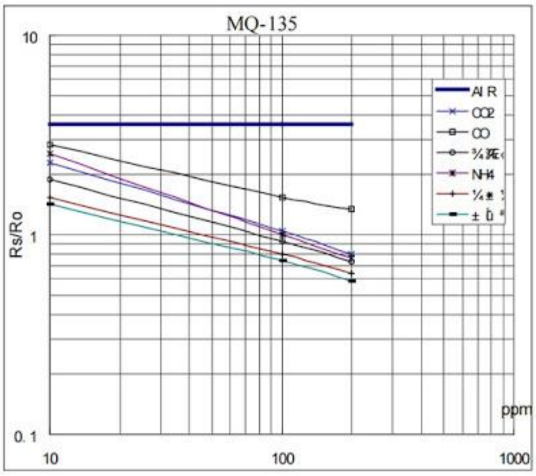

Fig.1: (Rs/Ro) vs part per million (ppm) graph

Table 1: AQMS index values indicator towards health

Index Values	Level of Health Concern	Cautionary Statement
0-50	Good	Low pollution without any bad effect on health
51-100	Moderate	Moderate pollution that does not pose any bad effect on health
101 - 200	Unhealthy	Worsen the health condition of high risk people who is the people with heart and lung complications
201-300	Very Unhealthy	Worsen the health condition and low tolerance of physical exercises to people with heart and lung complications. Affect public health

$$AQI = \frac{\text{Current Pollution Level}}{\text{Pollution standard level}} \times 100 \quad (1)$$

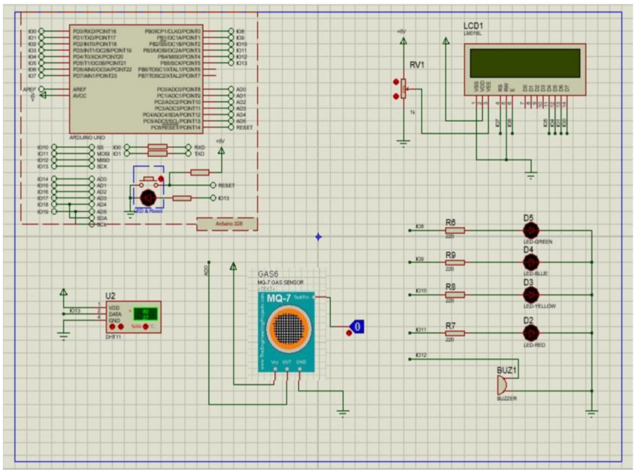

Fig.2: Basic circuit schematic diagram of the AQS using Proteus 8 Professional.

The system is simulated prior to designing the printed circuit board (PCB), using the Proteus 8 Professional software. Fig.2 shows the AQMS circuit schematic diagram. The PCB process are done in-house. PCB circuit diagram is designed using the same software, Proteus 8 Professional software. The design is then transferred onto the copper board for an etching process as a standard PCB circuit fabrication process. Components except the Arduino Uno are mounted on the PCB board are shown in Fig. 3. As referred to the DHT11 datasheet [13], the digital temperature and humidity sensor is a complex sensor that offer a calibrated digital signal output of the measured temperature and humidity. The DHT11 is a reliable component and stability [16].

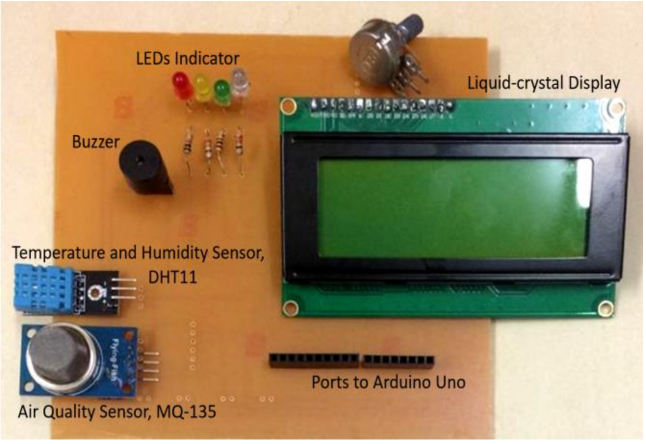

Fig.3: Mounted components on the AQMS PCB

The DHT11 consists of the humidity sensing parts are fabricated from a moisture holding substrate sandwiched by two (2) electrodes between them as shown in Fig. 4. The change in the environment humidity will cause the changes in the substrates conductivity and also the resistance between the electrodes. The simple integrated circuit in the DHT11 will then process the information collected from the conductivity and resistance value.

The DHT11 that also consists of a thermistor known as a variable resistor act as the temperature sensor. It has a layer of a semiconductor materials such as ceramics or polymers to show significant changes in resistance with just a small change in temperature. It uses the negative temperature coefficient (NTC), where the resistance decreases with an increase of temperature. Its measurement range is from 20-90% RH for humidity and 0-50 ℃ for temperature.

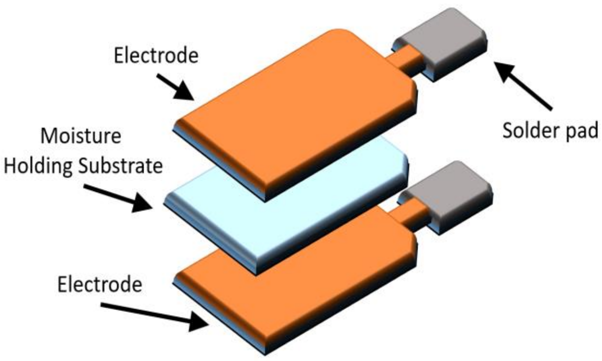

Fig.4: Humidity sensing fabrication layout

3. Result and Discussion

The AQMS prototype has successfully been developed. The LED on the AQMS is configured to light up according to Table 1. Whereases, table 2 depict LED configuration according to the AQI Reading. Upon air detection, the AQI will be measured, LCD will display the reading of the temperature and humidity immediately as well as the AQI reading. This will follow with the LED indicator.
Fig. 5 shows the flowchart of how the AQMS works. Fig.6 to Fig. 8 is the image of the AQMS prototype being tested. The unhealthy and very unhealthy AQI is tested using cigarette smoke. The amount of the smoke controls the result. When the air quality index is more than 100 but less than 200, the yellow LED will light up and the alarm system will turn on to notify that the air is nearly to a hazard level. Fig. 8 shows when the AQMS senses the AQI level higher than 100, the red LED will light up together with the alarm system. .

Table 2: LED configuration according to the AQI Reading

AQI Reading	LED Indicator	Buzzer/ Alarm
Reading > 200	RED	ON
100 < Reading <200	YELLOW	ON
50 < Reading <100	BLUE LED	OFF
Reading < 50	WHITE LED	OFF

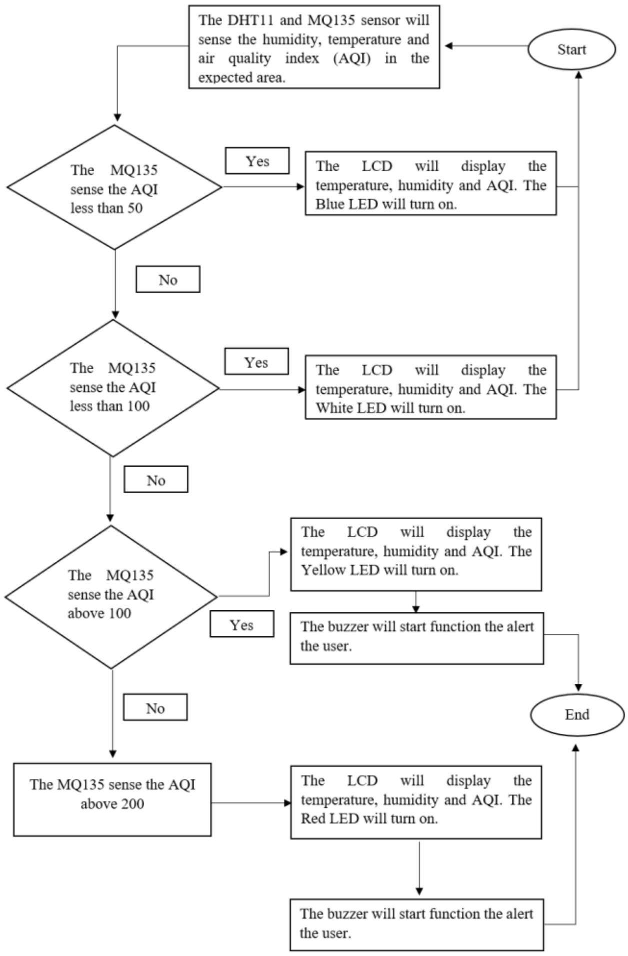

Fig.5: AQMS operation flowchart

The AQMS can be modified with an internet of things (IoT) elements such as Wi-Fi module or Bluetooth module, to collect and save the reading points into a database system. This may need more input/output pin. An Arduino Mega can be a good option to replace the existing microcontroller [17].
The AQMS is being tested by taking the AQI reading at various location in Pasir Gudang. Table 3 shows the average of the data measured in Pasir Gudang in general. AQMS data are collected specifically at Universiti Teknologi MARA Johor Campus, Pasir Gudang, Malaysia from morning to night, for two weeks. Morning data are taken between 8.00 am to 10.00 am, noon is between 12.00 pm to 2.00 pm, evening data are taken between 4.00 pm to 6.00 pm and night data are from 8.00pm to 12.00 pm. All times are referring to local times. The average measurement are then calculated and compared to the DoE data, which are gathered from the Air Pollutant Index of Malaysia (APIMS) website, prepared by the DoE.
Humidity causes a reduction in resistance as water vapour adsorbs on the sensor's surface. A compensation circuit or method for temperature and humidity dependency should be considered when using sensors. A signal conditioner has been used to amplify and extend the range of the sensor reading for more precise result [18].
From the data shown in Table 3, there is a slightly different reading between the AQMS and DoE. However, the percentages

of discrepancy are very low. This shows that the AQMS is nearly accurate in its measurement.

Fig.6 : AQMS sense a moderate level of AQI

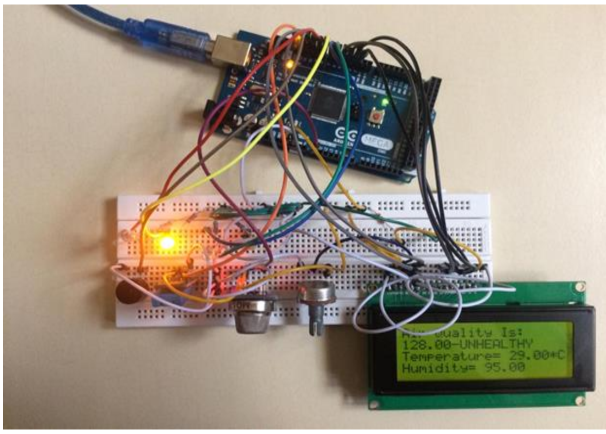

Fig.7: AQMS sense an unhealthy level of AQI

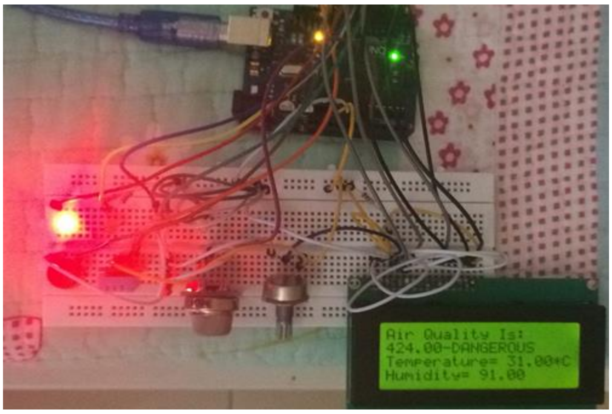

Fig.8: AQMS sense a very unhealthy level of AQI

It is also observed that Pasir Gudang has a moderate air quality level. Pasir Gudang is known as one of the biggest industrial bases in Malaysia where local and foreign companies invest in many types of industries including fertilizers, steel mill, petrochemical, palm oil refinery, cement, chemicals, shipping, offshore rigs, electronics and others since 1977 [19] with two world-class transhipment ports; Pasir Gudang and Port of Tanjung Pelepas. This may be one of the reasons of a moderate level of air quality.

It is impossible for people to avoid exposure mostly in urban areas, knowing concentrations are not sufficient to reduce potential adverse effects. By monitoring air quality, individuals could avoid such exposure by knowing the concentrations and also being aware of the risk caused by exposure to them. This includes for example to proximity to vehicle emissions, either for social purposes such as eating at street cafe or exercising along busy roads or indoor environments caused by combustion emissions such as smoking, cooking, fire crackers and burning candles [20].

Table 3: Comparison between the AQMS measurement and Malaysian Department of Environment Malaysia (DoE) for Pasir Gudang, Johor, Malaysia.

Session	Reading	AQMS	DoE
Morning	Air Quality	47	51
	Temperature (˚C)	28	25
	Humidity	95	89
Noon	Air Quality	50	50
	Temperature (˚C)	32	32
	Humidity	90	70
Evening	Air Quality	48	54
	Temperature (˚C)	30	30
	Humidity	90	70
Night	Air Quality	45	52
	Temperature (˚C)	30	27
	Humidity	95	89

4. Conclusion

AQI monitoring is very important for all residents to minimize the activities which contribute in increasing AQI value. The developed prototype systems are capable of monitoring various indoor and outdoor air pollutants in real time. To live a healthier life, the proposed Arduino-based system where it senses the levels of harmful gases temperature, and humidity is relevant. This work has shown the development of a low-cost mobile AQMS that is useful for end user. It helps to develop awareness and user can take preventive measures against indoor or outdoor air conditions around them.

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