Information Sciences Letters

Volume 12
Issue 4 *Apr. 2023*

Article 13

2023

An Internet of Things Based Air Pollution Detection Device for Mitigating Climate Changes

A. Alshahrani
Arab Open University, Kingdom Saudi Arabia, Amena_mahmoud@fci.kfs.edu.eg

A. Mahmoud
Department of Computer Science, Faculty of Computers and Information, Kafrelsheikh University, Kafrelsheikh, Egypt, Amena_mahmoud@fci.kfs.edu.eg

S. El-Sappagh
Faculty of Computer Science and Engineering, Galala University, Suez, Egypt\\ Information Systems Department, Faculty of Computers and Artificial Intelligence, Benha University, Banha, Egypt, Amena_mahmoud@fci.kfs.edu.eg

M. S. Ali Elbelkasy
Information Systems Department, Higher Institute of Management and Information Technology, Kafrelsheikh, Egypt, Amena_mahmoud@fci.kfs.edu.eg

Information Sciences Letters
An International Journal

http://dx.doi.org/10.18576/isl/120413

An Internet of Things Based Air Pollution Detection Device for Mitigating Climate Changes

A. Alshahrani[1], A. Mahmoud[2,], S. El-Sappagh[3,4] and M. S. Ali Elbelkasy[5]*

[1] Arab Open University, Kingdom Saudi Arabia
[2] Department of Computer Science, Faculty of Computers and Information, Kafrelsheikh University, Kafrelsheikh, Egypt
[3] Faculty of Computer Science and Engineering, Galala University, Suez, Egypt
[4] Information Systems Department, Faculty of Computers and Artificial Intelligence, Benha University, Banha, Egypt
[5] Information Systems Department, Higher Institute of Management and Information Technology, Kafrelsheikh, Egypt

Received: 2 Nov. 2023, Revised: 12 Dec. 2023, Accepted: 21 Jan. 2023
Published online: 1 Apr. 2023.

Abstract: Climate Change, a key stabilizing factor, has now exceeded critical thresholds. The high energy consumption of cities is a major contributor to climate change because of CO2 emissions. In addition to the rise in urban populations throughout the worldwide, the complexity of today's cities and the strain they put on limited resources means that the causes and consequences of climate changes become even more concentrated. Internet of Things (IoT) advancements provide several possibilities for reducing the effects of climate change by merging existing information, design techniques, and breakthrough technology. The current state of monitoring technology is subpar; it is insensitive, inaccurate, and requires laboratory examination. Consequently, new, and better methods of surveillance are required. Air pollution is one of the main causes of climate change. We suggest a new IoT-based monitoring device for air pollution to address the shortcoming of the current setup. Gas sensors, Arduino IDE, and Wi-Fi module were used to assemble the IoT kit. The air is analyzed by the gas sensors, and the results are sent to the Arduino software development environment. By using a WiFi module, the Arduino IDE may send data to the monitor. The resulting device may be deployed in different cities to monitor the levels of air pollution with little cost, easy to use and high accuracy.

Keywords: IoT, gas level, sensor data management, data analytics.

1 Introduction

Since air pollution is a major risk to human health and the global ecosystem, it is crucial that efforts for reducing it to be continued [1]. Both climate change mitigation activities and clean air measures may contribute to lowering global warming by reducing emissions of greenhouse gases. There may also be costs associated with lowering pollution, especially if doing so results in more warming of the atmosphere rather than less. There are intricate feedback loops between air pollution and climate change. Increasing concentrations of greenhouse gases (GHGs) disrupt the energy equilibrium between the atmosphere and the Earth's surface, which may cause changes in atmospheric temperature and, therefore, atmospheric chemistry [2]. This energy balance may also be affected by emissions of air pollutants, either directly (such as black carbon) or indirectly (via formation of sulphate and ozone). Consequently, there are repercussions for both climate change and pollution control [2].

Given the correlation between emissions and air pollution, this special issue explores the potential advantages of cutting down on both long-lived GHGs (which cause climate change) and air pollutants (which have negative effects on human health, ecosystems, and the environment) [3]. To achieve reciprocal advantages for climate and health, it is important to understand the effect of lowering particulate matter (PM) on climate change [4]. Reductions in PM may have nuanced consequences since PM contains a wide variety of chemical components with distinct physical characteristics; some contribute to temperature rise (like black carbon) by soaking up solar radiation, while others (like sulphates) have the opposite effect [4].

Nitrogen oxides, methane, and other volatile organic compounds emitted to the atmosphere mix in the troposphere to form an ozone molecule, a major contributor to poor air quality [5]. High amounts of ground-level ozone harm human health and plants, reducing agricultural yields and other benefits. Ozone is a short-lived greenhouse gas that contributes to global warming. Incomplete combustion of carbon-based fuels results in the release of carbon dioxide (CO2) and other pollutants, such as particulate matter (PM) (aerosols), which may either chill or warm the planet's temperature depending on whether or not they reflect or absorb the sun's rays [6]. Black carbon (BC) is one kind of PM that has been shown to significantly absorb solar radiation despite its short atmospheric lifetime (about a week). BC is anticipated to contribute

*Corresponding author e-mail: amena_mahmoud@fci.kfs.edu.eg

to global warming because of emissions from residential burning of solid fuels, especially indoors, and high emitting diesel engines. Particulate matter (PM) is a key contributor to local air pollution, with varying quantities depending on the source of combustion and its effect on the climate. The negative health effects of PM exposure are well-documented [7]. This is especially true in underdeveloped regions, where 1.8 million premature deaths annually are attributed to BC and other respiratory illnesses caused by indoor smoke pollution caused by the widespread use of solid fuels for cooking purposes. High levels of BC pollution in metropolitan areas of developing nations are mostly attributable to the operation of polluting businesses and the use of outdated automobiles [7].

Many possibilities exist for applying the Internet of Things (IoT) to today's most urgent problems, and it is widely expected to have the most significant effect [8]. Considering the increasing complexity of contemporary cities and the strain they exert on all available resources; smart cities should take a more proactive stance. Since most people now reside in urban regions due to population expansion and rural-to-urban migration, problems will arise in ever-increasing concentrations. IoT may assist urban areas in maintaining stable demographics by reducing or eliminating outmigration.

Air pollution is a problem that endangers people's health, destroys assets, and slows economic development. By reducing harmful emissions, slowing climate change, and, most importantly, saving lives [8]. The proposed research assessed the potential of reducing BC emissions to mitigate climate change by suggesting an Iot model that estimates the current CO_2 level and keeps a historical analysis of the measurements. We believe that our study will help to promote healthier cities and investments in cleaner forms of energy.

In this study, we outline the process of implementing a model for detecting pollution via the Internet of Things. The second section of this paper examines the methods currently used to monitor air quality. In section three, we detail the technological methodologies which our air quality monitoring system uses. The framework of the air quality monitoring system we propose is discussed in section four. In section five, the process followed during the creation of the air quality monitoring system is outlined. Limitations and future work are mentioned in section six, and finally, conclusions are reported in section seven.

2 Related Work

AirTick was one IoT software that uses smartphone cameras as a proxy for air pollution sensing by using machine algorithms and image recognition to analyze photos across cities at a minimal cost. The study demonstrated how IoT applications are enhancing real-time monitoring of air quality [9].

A wireless sensor network (WSN)-based system for assessing air pollution contamination was described by Mujawar et al. [10] for use in the Indian city of Solapur. By monitoring the electrical conductivity of the sensing layer, micro-sensor nodes may identify the presence of the target gas. As soon as the gases collide, conductivity changes when these particles integrate into the sensor's surface. In addition, to use a semiconductor sensor at the vehicle's tailpipe to detect air pollution levels then send that value to the microcontroller [10].

Peterová and Hybler [11] and Bhatt et al. [12] showed that environmental sensing may reawaken people's concern and interest in reducing pollution in their communities. Exposure Sense is a lightweight participatory sensing framework for monitoring one's day-to-day life on the go [13].

The Android application of Re et al. [14] provided users of data on the quality of the air they are breathing. This program offered a ubiquitous and unobtrusive monitoring framework, ready to warn users on their daily air pollution exposure by fusing information about user areas with metropolitan air quality data collected by monitoring stations [15].

Combes et al. [16] employ neural network algorithms in smart monitors to attribute a pollutant to its point of origin in real time, allowing for management situations previously impossible. In urban areas, the intensity of transportation-related pollution can be predicted using Artificial Intelligence (AI) that makes use of pollutants and environmental data (solar irradiation, humidity, and temperature) [16]. This allows for management responses to be taken to reduce pollution impacts, such as congestion charging and traffic restrictions. Recently, artificial intelligence used in modern networked platforms may utilize information gathered by cameras, automobiles, and radar sensors to enhance urban traffic patterns and decrease emissions from idle vehicles [17].

To enhance and support the research in Air pollution detecting, we proposed a new IoT-based monitoring system for air pollution to address the shortcoming of the current models. Gas sensors, Arduino IDE, and Wi-Fi module were used to assemble the IoT kit. The air is analyzed by the gas sensors, and the results are sent to the Arduino software development environment. By using a WiFi module, the Arduino IDE may send data to the monitor. The resulting model may be deployed in different cities to monitor the levels of air pollution with little cost, easy to use and high accuracy.

3 Materials and Methods

The rapid growth of IoT has gained a great deal of interest in the applications of potential in improved systems for monitoring of environment. The goal of the proposal is to improve and reinforce the working of Audit Status Monitoring. Coordinator Level, Management Level, Auditor Level, User Level, and State Web Coordinator Level are the five streams that make up the overall scope.

By standardizing and integrating environmental activities, such as studies of air emissions, the suggested study offers a framework for pollution control. The current approach helps users, especially businesses, to monitor the dangers of improperly discarding harmful material, while also increasing conformity with environmental requirements.

The following objectives are considered while proposing this device:

1) Creating a centralized hub for monitoring and managing environmental initiatives across all industries.
2) Monitoring compliance with ISO 14001 and other industry specific environmental standards.
3) Auditing real-time environmental processes view.
4) Receiving alerts when predetermined thresholds are crossed.
5) Highlighting the risks associated with crossing these thresholds.

During the development of the proposed device, we achieved the previously mentioned objectives. Additionally, the device was tested and recorded accurate results with changing of the surrounding environment.

The following subsections presents the methodologies used to implement the proposed Iot air pollution monitoring system.

3.1 Wireless Sensor Network (WSN)

For data collection, sensor nodes in a WSN can communicate wirelessly with one another. The capacity for data storage and processing in WSNs is limited. Data at a low frequency from a distance can be monitored with the help of wireless sensor networks (WSNs).

The sensor network was built with the express purpose of detecting and cataloguing all airborne pollutants in a given region. In this research, carbon dioxide levels were measured as a proxy for the quality of indoor air. The expense of implementing a WSN would be less in comparison to the cost of the conventional wired infrastructure. Adding new nodes to the network does not necessitate major adjustments or redesign. Additionally, WSN is highly adaptable and may quickly change to accommodate new requirements.

3.2 Internet of Things (IoT)

The Internet of Things (IoT) is the network of physical objects (or "Things") that we use every day that can also connect to other devices over the internet and exchange data with them [18]. Things: microcontroller (Arduino), Wi-Fi module (WiFi), gas sensors, and a mobile operating system (Android). Together, these elements form a framework within; where the necessary data can be gathered, stored, and retrieved in order to address the problem.

Core to the IoT paradigm are the application layer, network layer, and sensor layer. The sensor layer is responsible for processing information gathered from the outside world. Sensing data is sent to the network layer. As an intermediary between the sensor layer and the application layer, this layer facilitates communication between the two. As a last step, the application layer provides tools for analyzing and using the information gathered at the previous two stages (transport and presentation). The proposed model has a three-level structure.

3.3 Android Platform

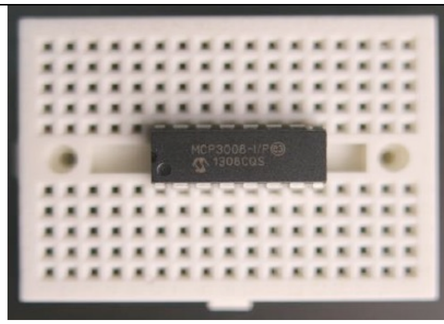
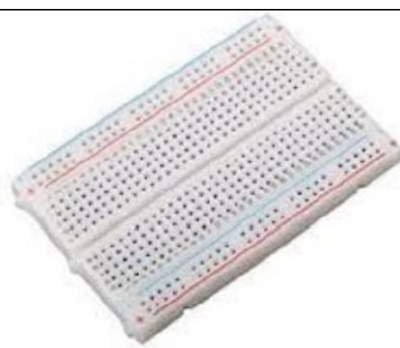
Recent innovations in smartphones have shifted attention away from older types of mobile phones. These days, everyone uses their phone for more than just talking, as it has become an indispensable tool in their daily lives. Android technology currently dominates the electronic sector.

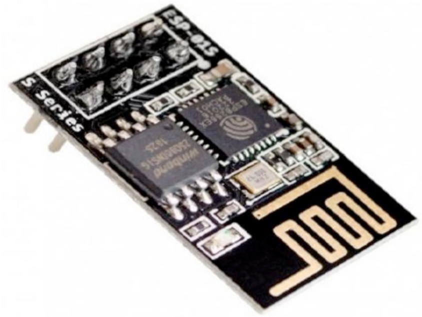
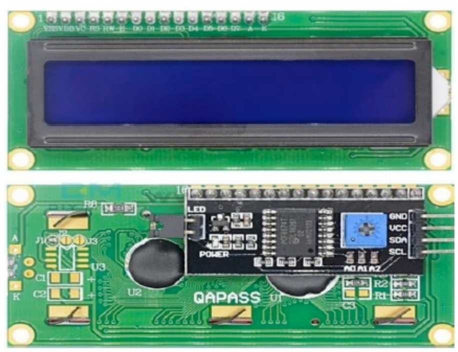
In recent years, both mobile phones and the Android operating system have become increasingly commonplace. When developing the IoT-Android app, we relied on the Java programming language, the Eclipse IDE, the Android Application Development Tools (ADT), and the Android Software Development Kit (htt2). The IoT-app is able to give users information on the air quality in their immediate area by utilizing the IoT, sensors, and ordinary web pages. If a user is going for a location, the system predicts the pollution level along the entire route and displays a warning if the level is too high to allow the user to reroute his trip.

3.4 hardware Materials

In order to implement an Iot model, we have established the Arduino sketch and made the necessary connections. The air quality is determined via a gas sensor and an Arduino software. CO_2 gas detection, for instance, can include the use of a CO_2 sensor (MQ-2). Table 1 details the components of the recommended model.

Table 1: Components of the recommended device

Device name	**Device sample**	**Description**
MCP3008		The MCP3008 is an inexpensive analog-to-digital converter that features 8 channels and 10 bits of resolution. This ADC has the same level of precision as an Arduino Uno, and because it has eight channels, it can read a significant number of analogue signals from the Raspberry Pi. Unit price: 3,15 € Manufacturer: Microchip Technology / Atmel Country of production: Germany
FC-22 gas sensor	 	Gas leakage detection is made easier with the help of the gas SensorFC-22 (MQ_2) module (in home and industry). It can detect H_2, LPG, CH_4, CO_2, alcoholic beverages, smoke, or propane, among other things. Since it has a high level of sensitivity as well as a quick response time, measurements can be conducted as quickly as possible. Utilizing the potentiometer to alter the sensor's sensitivity is one of the available options. Unit price: $20.65 Manufacturer: FastTech Country of production: China
Bread Board		In the world of electronics prototyping, a breadboard serves as a construction platform. In the 1970s, a solderless breadboard, also known as a plug board or a terminal array board, became commercially accessible. These days, the term "breadboard" is often used to refer to these types of boards. The word "prototype" can alternatively be referred to as "breadboard." It is possible to reuse the solder less breadboard because there is no need to solder the connections. Because of this, it is very easy to use for the purpose of building temporary prototypes and experimenting with the design of circuits.

ESP8266		The ESP8266 WiFi Module is a self-contained SOC that comes with an integrated TCP/IP protocol stack. It can provide access to your WiFi network for any microcontroller that you choose to use. The ESP8266 is capable of either serving as a host for an application or offloading all of the Wi-Fi networking tasks to another application processor. Unit price: $18 Manufacturer: Espressif Systems Country of production: China
Hi Link		This is a relatively compact module that can generate 5 volts from either 120 VAC or 230 VAC; as a result, it is ideal for use in smaller applications that require a power source that generates 5 volts from the mains. Unit price: $10 Manufacturer: Shenzhen Hilink Electronics Country of production: China
LCD Screen		I2C LCD is a display module that is simple to operate and can help simplify the display process. Utilizing it can make the production easier, allowing creators more time to concentrate on the essential aspects of their work. We designed the Arduino library for the I2C LCD, and all the user needs to do to get complicated graphics and text display features is type a few lines of code. Unit price: $12 Manufacturer: DORHEA Country of production: China
Servo Motor		In addition to stepper motors, there are also servo motors that are both affordable and compact. Because of their compact size and light weight, Raspberry Pi servo motors are employed in a wide variety of applications due to the ease with which they may be controlled. Servo motors, as opposed to stepper motors, just require a single GPIO in order to be controlled.

4 Proposed Approach

The suggested model for industry-based pollution control seeks to standardize and integrate environmental activities such as air emissions analysis, energy management, and waste reduction. Chemical spills, oil spills, and inappropriate disposal of harmful chemicals are all avoidable with the use of such models, which also improve compliance with environmental standards and laws.

The following are some of the functions of the proposed an air pollution detection model:

- Real-time air quality indexes for any location that estimate daily air quality by checking CO_2 ratio.
- Health concerns associated with a decline in air quality.
- Location-based air quality reporting and a historical analysis for the results.

It also features a three-stage process:

First Step: Determine the Concentrations of CO_2 in the Air and Within the Sensor-Equipped Zone of Interest.

Step Two: Design a Convenient, Transportable User Interface by using an Android app. This user interface should be able to notify the user with the level of air pollution in their region and present the results on the LCD display that is attached to the device.

Step Three: Make Analytical Module Air Quality Predictions. A method for detecting air pollution is described in Fig. 1.

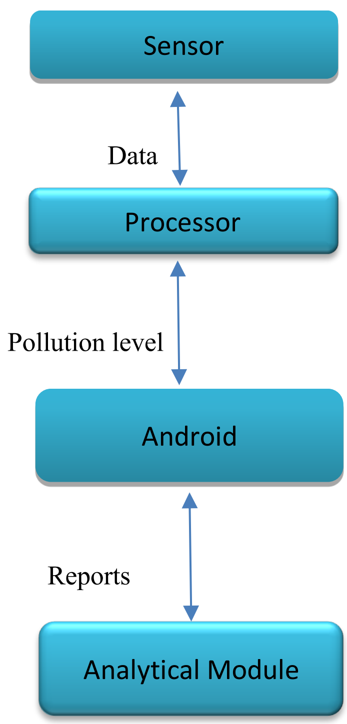


Fig. 1. System implementation

One of the most harmful kinds of airborne toxins is termed "PM 2.5," and it may be measured in a number of different ways. The "PM" still refers to "particulate matter," and the "2.5" means that the particles are at most 2.5 m in width, which is about the size of a single bacterium. Such pollution is especially dangerous because it may get lodged in the lungs, where it can cause chronic health problems including asthma and lung infection if left untreated. When PM 2.5 concentrations in the air rise over 35 micrograms per cubic meter, this may become a serious health risk. Keeping PM 2.5 levels below 10 g/m3 is recommended by the World Health Organization.

5 Implementation and Results

The proposed air pollution detection device is developed using IoT techniques. In the first phase, data is gathered through gas sensors linked to an Arduino board and uploaded to a cloud service. In the next stage, we see how this data may be accessed through the Android platform. To do this, Gas sensors monitor the local gas content and provide the necessary data. Normal values for the gas sensor are shown in table 2.

Table 2: Gas Sensor details

Sensor	Gas	Description	Range
	Co_2	It can detect Co_2 concentration anywhere from 20 to 2000 ppm	0 -100 (Normal) 101 – 800 (Risky) 801 – 2000 (Very high)
MQ_2	Methane	It can detect Methane leakage which is useful in gas and industry.	0 -1000 (Normal) 1001 – 15000 (Risky) 15001 – 50000 (Very high)
	Air Quality	Responsible for a wide range of gas detection like smoke and alcohol.	0 -500 (Normal) 501 – 1500 (Risky) 1500 – 2000 (Very high)

The used gas Sensor FC-22 (MQ_2) module is useful for gas leakage detection (in home and industry). It is suitable for detecting H_2, LPG, CH_4, CO_2, Alcohol, Smoke, or Propane. It can detect the concentration of CO_2 in air that can vary from 20 to 2000 pm. For pm values between 0 – 100, it will give no effect with green color, as shown in fig. 2. However, for pm values more than 100, it will give risky alert with red color, as shown in fig 3.

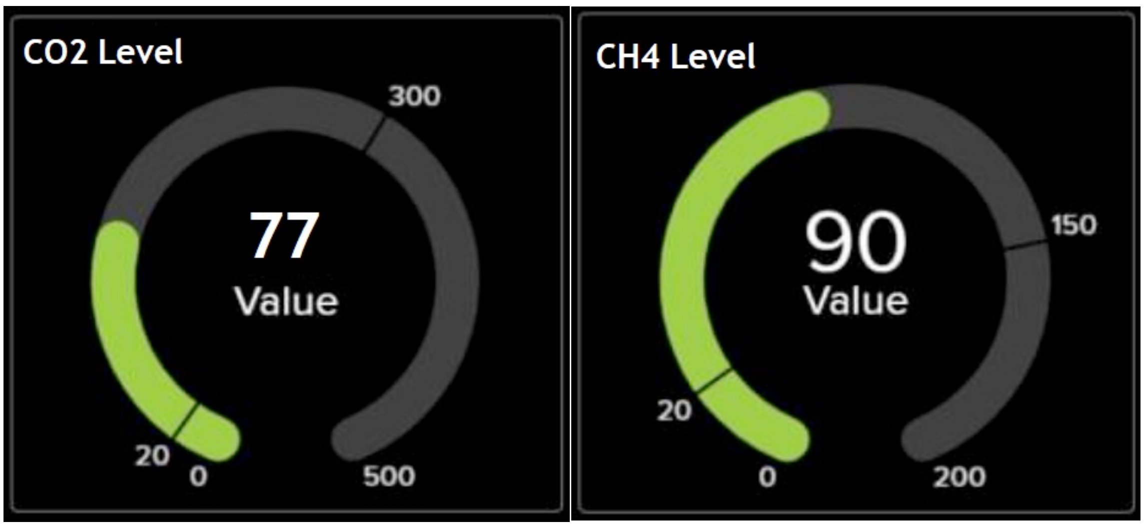


Fig. 2. Co_2 and CH_4 accepted level

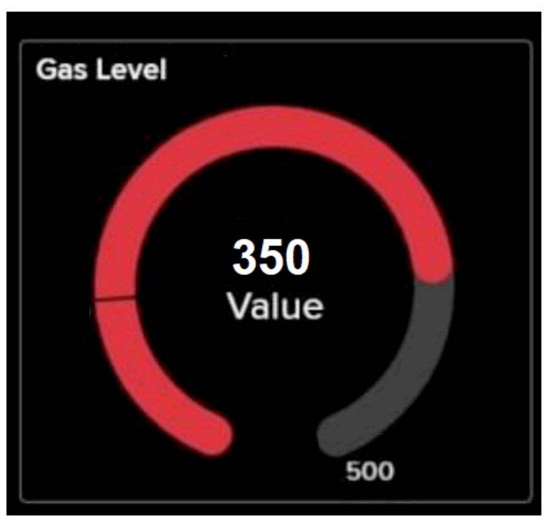


Fig. 3. Co_2 risky level

The collected data from the sensor is stored in a database to give the possibility for displaying historical data for the detection process. Fig. 4 presents the previous readings of the system and fig. 5 displayed a sample of the chart for gas detection in May and June months.

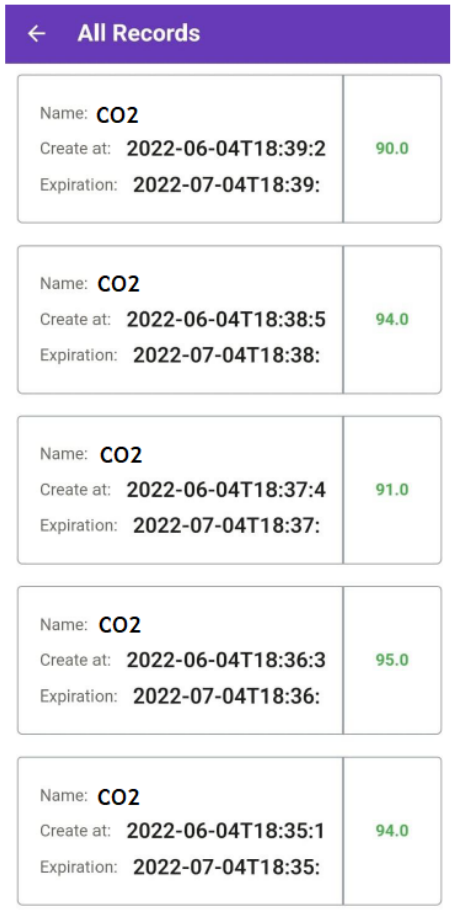


Fig. 4. The previous readings of the system

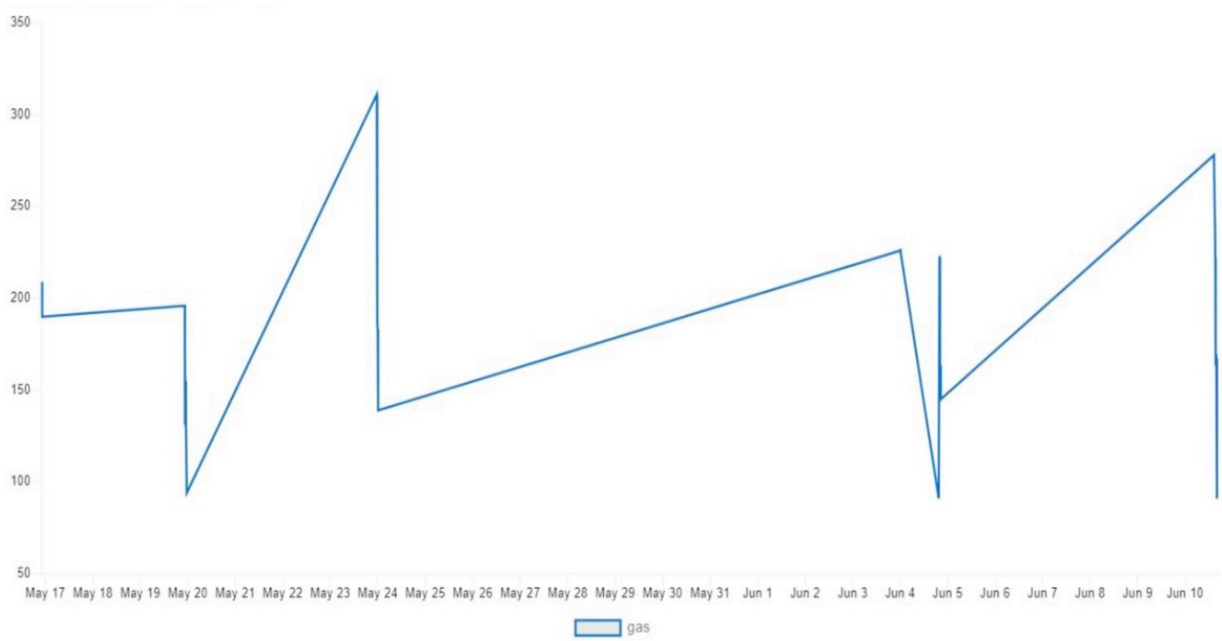


Fig. 5. analysis of gas level measurements

6 Limitations and future work

The proposed device was implemented in the faculty of computers and information, Kafrelsheikh university, Egypt. The main purpose was to detect and report the mentioned gas levels that affect climate change. The device was tested by the staff of computer science department at the faculty and some of the staff in the physics department at the faculty of science. The results were compared to other applications like AirCare and it gives accurate results.

The design of the proposed device has some limitations like the used sensor, it is responsible for limited number of gases to detect. We propose to enhance the model by adding more sensors for other kinds of gases. Besides, the used battery is limited in voltage, it will give better results if the designed model was connected to a better power AC supplier. Regarding the functionality of the system, we propose to enhance it by adding machine learning algorithms to predict the pollution ratio in a certain place depending on the historical measurements. Also, to connect the model with other applications like Google map to give better and accurate results.

7 Conclusions

Monitoring of air, especially pollution detection, is considered highly vital and necessary. This approach is expected to support reducing the number of pollutants in the air. Humans are thought to be blamed for the pollution and hazardous environment. This is a major problem on a global scale. As a result, it has been suggested to develop a Raspberry Pi module to be used as a monitor to a variety of environmental conditions and keeping track of air pollution and CO2 ratio. It is a low-cost, accurate, and efficient way of monitoring. The study of diverse trends in environmental indicators is aided by the monitoring of accumulated data in cloud storage, which warns the public appropriately.

Ethics Statement

This research did not require ethical approval. Data Availability Statement Data associated with the manuscript is public and has been referenced appropriately.

Acknowledgement

The author would like to thank Arab Open University, Saudi Arabia for supporting this study.

Conflicts of Interest Statement

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

[1] https://www.ipcc.ch/2022/02/28/pr-wgii-ar6/ [Online Resource].

[2] V. Ramanathan and Y. Feng. Air pollution, greenhouse gases and climate change: Global and regional perspectives. *Atmospheric Environment*, **43**(1), 37-50 (2009).

[3] Hannah Ritchie, Max Roser and Pablo Rosado. CO_2 and Greenhouse Gas Emissions". Published online at OurWorldInData.org. Retrieved from: *'https://ourworldindata.org/co2-and-other-greenhouse-gas-emissions, 2020* [Online Resource].

[4] Fuzzi, S., Baltensperger, U., Carslaw, K., Decesari, S., Denier van der Gon, H., Facchini, M. C., Fowler, D., Koren, I., Langford, B., Lohmann, U., Nemitz, E., Pandis, S., Riipinen, I., Rudich, Y., Schaap, M., Slowik, J. G., Spracklen, D. V., Vignati, E., Wild, M., Williams, M., and Gilardoni, S. Particulate matter, air quality and climate: lessons learned and future needs. *Atmos. Chem. Phys*., **15**(14), 8217–8299 (2015).

[5] Daniel J. Jacob, Darrell A. Winner. Effect of climate change on air quality. *Atmospheric Environment*, **43**(1), 51-63 (2009).

[6] Tainio, M., Juda-Rezler, K., Reizer, M. et al. Future climate and adverse health effects caused by fine particulate matter air pollution: case study for Poland. *Reg Environ Change*, **13**, 705–715 (2013).

[7] Ki-Hyun Kim, Ehsanul Kabir and Shamin Kabir. A review on the human health impact of airborne particulate matter. *Environment International*, **74**, 136-143 (2015).

[8] Nikhita Reddy Gade, Nishanth Reddy Gade and G. J. Ugander Reddy. Internet of Things (LOT) for Smart Cities-

The Future Technology Revolution. *Global Journal of Computer Science and Technology: E Network, Web & Security*, **16**(1), 2016.

[9] Aviva Rutkin. Worth a thousand words. *New Scientist*, **229**(3060), 2016.

[10] T. H. Mujawar, V. D. Bachuwar, and S. S. Suryavanshi. Air pollution monitoring system in Solapur city using wireless sensor network. *in Proc. Publ. Int. J. Comput. Appl. CCSN*, 11–15 (2013).

[11] R. Peterová and J. Hybler. Do-it-yourself environmental sensing. *Procedia Comput. Sci*., **7**, pp. 303–304, Dec. 2011.

[12] N. A. Bhatt, M. R. Babu, and J. A. Bhatt. Automation testing software that aid in efficiency increase of regression process. *Recent Patents Comput. Sci*., **6**(2), 107–114 (2013).

[13] B. Predic, Z. Yan, J. Eberle, D. Stojanovic, and K. Aberer. ExposureSense: Integrating daily activities with air quality using mobile participatory sensing. *in Proc. IEEE Int. Conf. Pervasive Comput. Commun*. Workshops (PERCOM Workshops), 303–305 (2013).

[14] G. L. Re, D. Peri, and S. D. Vassallo. A mobile application for assessment of air pollution exposure. *in Proc. 1st Conf. Mobile Inf. Technol. Med. (MobileMed)*, 1–4 (2013).

[15] A. Tamayo, C. Granell, and J. Huerta. Using SWE standards for ubiquitous environmental sensing: A performance analysis. *Sensors*, **12**(9), 12026–12051(2012).

[16] Combes B, Herweijer C, Ramchandani P, Sidhu J. Fourth industrial revolution for the earth: harnessing artificial intelligence for the earth. *World economic forum. Retrieved from https://www.pwc.com/gx/en/sustainability/assets/ai-for-the-earth-jan-2018.pdf*.

[17] Bell M, Goodman P, O' Brien J and Namdeo A. A congestion sensitive approach to modelling road networks for air quality management. *Int J Environ Pollut* , **54**(2/3/4), 213–221(2014).

[18] J. A. Stankovic. Research directions for the Internet of Things. *IEEE Internet Things J.*, **1**(1), 3–9 (2014).