Identification of Hazardous Substance on Air in Different Industrial Sites by Using IoT Based Air Quality Monitoring System

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Abstract

Air pollution is one of the pollutions that basically a mixture of various dangerous particles and toxic gases in the environment, its affect the human respiratory system. The level of pollution has increased with times by numerous reasons, like the increase in population, increased vehicle use, industrialization and urbanization. These variables have a negative impact on human welfare by directly impacting the health of those who are exposed to it. To keep an eye on in this research a prototype IoT based Air Pollution Monitoring System has been developed which will monitor and measured the concentrations of main air pollutant gases like CO2, smoke, benzene, LPG gas, CH4, CO, SO_2 and NO_2. It also measured the humidity and temperature with air quality. This research involved hardware development in which hardware development includes the Arduino UNO, several gas sensors (MQ-2, MQ-4, MQ-7, MQ-135), Humidity and temperature sensor AM2302/DHT22**,** a buzzer, Bluetooth (HC-06) and LCD display. Sensors used in the presented work have been interfaced to their respective board in order to perform detection of various parameters in real time and obtain detection results simultaneously. It can monitor the pollution level and current reading can be viewed from anywhere using computer or mobile by Blue serial beta app. The collected data was compared with standard atmospheric value of different toxic gas level. Data was gathered from Construction site, Steel Industry, Garments industry (Indoor) and metal cutting sites near by Dhaka city in Bangladesh.

Keywords
Internet-of-Things (IoT), Air quality monitoring, Air pollution, MQ gas sensors, Arduino UNO and Sensor.

1. Introduction
Air pollution has become a prominent setback for the world over the years. Industrialization, deforestation these are the main reasons for air pollution. Air pollution occurs when unhealthy or unsustainable amounts of pollutants are released into the Earth's atmosphere, including gases (such as carbon dioxide, carbon monoxide, sulfur dioxide, nitrous oxides, methane and chlorofluorocarbons), particulate matter (both organic and inorganic) and biological molecules. The component of dust in Dhaka city is increasing day by day, which is very harmful for human health. Every person is affected by this pollution. In Dhaka, the two major sources of air pollution are industrial and vehicle emissions. Thousands of ready-made garment manufacturers (RMG), chemical industries, steel industry, plastics industry, brick kilns, pharmaceutical industries, and other industrial emission sources are main responsible for air pollution (Alam et al. 2018). The growing body of epidemiological evidence has led to the negative consequences of ambient air pollution on health, which leads to heart disease, in recent years. CO, NO2, and particle matter are examples of environmental air pollutants. These harmful air pollutants are linked to a higher level of integrity as a result of cardiovascular disease (Lee et al. 2014). Especially Particulate matter 2.5 micrometers (PM2.5) is formed by incomplete combustion of gasoline and naphtha, and biomass produces electricity with the help of steam. This particulate matter has the ability to enter deep into the lungs and bloodstream, causing illnesses.

In metal cutting site, Construction site, Steel Industry, Plastics industry, Garments industry and metal cutting sites is highly toxic gases are exhausted on regular basis. Workers of those site regularly gets affected by several kinds of respiratory diseases though inhaling those gases. Silicosis asbestosis, asthma, chronic obstructive pulmonary diseases, and pneumonia these of type of diseases are mostly prevalent due to inhalation of those toxic gases (Hoy & Brims 2017). Air quality monitoring system is a good platform for interfacing with many devices at the same time. Internet of Things and cloud computing are the most emerging technologies. Internet of Things is a concept or a paradigm in which without human interruption devices sense, identify, process and communicate with each other. Cloud computing is a contemplation of consuming the resource of remote servers such as storage, virtual machines, applications and utilities that are hosted on internet rather than building and maintaining infrastructure for computing in house (Jha et al. 2015). Internet of Things becomes very powerful when converges with Cloud computing. IoT cloud system provides a view on accessing IoT resources and capabilities in defined API, configuring and operating it on cloud. The data stored at the cloud can be recoup any time and the scenarios can be analyzed in a better way leading to the solutions for controlling air pollution to some extent (Kumar, & Jasuja, 2017).

Internet of Things (IoT) is nowadays finding peculiar use in each and every sector and plays a key role in our air quality monitoring system too. Our setup will show the air quality in PPM (Parts per Million) so that we can monitor it very easily (Sai et al. 2019). Air Quality Monitoring system developed by using several gas sensors such as MQ-2, MQ-4, MQ-7, MQ-135, Humidity and temperature sensor AM2302/DHT22 sensor which is sensitive to the natural gas, CH4 CO, SO_2 and NO_2 and Liquified Petroleum Gas (LPG). This device embeds the MQ 135 sensors, LCD Screen and Bluetooth HC-06 Modules with an Arduino UNO Microprocessor (Zulkifli et al. 2020). Air quality monitoring system could detect those bio-toxic chemicals at an early stage, alerting workers to leave the place as soon as possible and reducing the risk of respiratory disease. The monitoring system should be easy to use, small, and portable. It is not only feasible to diagnose respiratory disorders early through the use of air quality monitoring systems. A part of the integrated process is an air quality monitoring system. In this case, the monitoring system would be really useful and allows authorities to monitor air pollution in different areas and act against. It will alert both industrial area and authority through a short alert notification indicated using buzzer. This system has features for the people to monitor the amount of pollution on their mobile phones using the application.

1.1 Objectives

The main objective of this research work of IoT Based Air Quality Monitoring System is that to use numerous MQ gas sensors to increase the number of gases detected and motoring. This air quality monitoring device could thus alert users to a wide spectrum of harmful gases. There would be a comparison between the detected gas level and the amount of those gases in the atmosphere monitor air quality and keep it under control for a better future and healthy living for all. Due to flexibility and low-cost Internet of things (IoT) is getting popular day by day.

2. Literature Review

Pollution is increasing in an alarming rate every day. Air is the most sensitive element of the environment which is polluted momentarily by the elements emitted to air. To know the level of air pollution and air quality this proposed system is a wireless sensor network that works mainly monitoring the pollution happening in an Industrial area. Air quality monitoring and control has gained much animus lately because of the increased environmental awareness and the effect of air quality on many aspects of life. Besides the detrimental effects of toxic emissions on the environment and health, work productivity and energy efficiency are affected by air quality (Jamil et al. 2015). It is a low-cost monitoring system with cheap but here used efficient sensors for air quality measures. Some prior works, such as a vehicle-based smart environment monitoring system were introduced in previous. System uses air sensors to sense presence of harmful gases/compounds in the air and constantly transmit this data also reports it. The sensors interact with Arduino UNO which processes this data and transmits it over the application. Arduino is an open-source electronics platform based on easy-to-use hardware and software. Arduino boards are able to read inputs - light on a sensor, a finger on a button. This allows authorities to monitor air pollution in different industrial areas and act against it (Pal et al. 2017). On the other hand, the term “Internet of Things” (IoT) refers to the possibility of connecting sensors, actuators or any device to the Internet. It can lead to a significant change in our daily lives in the way we live and interact with the devices such as home appliances, smart meters, security sensors, HVAC systems, etc.

The IoT is a technological revolution that represents the future of computing and communications (Shinde et al. 2017). It essentially calculated the rate of harmful gas emissions, which are responsible for air pollution. To better understand the dangerous gasses and their consequences, an industrial air pollution monitoring system was implemented. The introduction of an industrial air pollution monitoring system (IAPMOS) approach will promote occupational health awareness among the workers (Leman et al. 2010). This study proposes air pollution and monitoring model which detects pollution in air on the basis of data mining algorithm. The sensor grid is used to detect the sensor values from different gas sensors. Data mining is used to calculate the pollutants from different industrial areas. Bluetooth module is used to connect the controller with client and the client connects with the server via web services. Wireless sensors are used to calculate the percentage of harmful gases present in the air that ultimately helps to provide the reduction in pollution (Raipure and Mehetre 2015). The air pollution monitoring system was designed to monitor and analyze air quality in real-time and log data to a remote server, keeping the data updated over the internet. Air quality measurements were taken based on the Parts per Million (PPM) metrics and analyzed using Microsoft Excel. The air quality measurements taken by the designed system was accurate. The result was displayed on the designed hardware's display interface and could be accessed via the cloud on any smart mobile device (Okokpujie et al. 2018).

The Arduino UNO in WSN acts as a medium to sensor for providing the data to the Raspberry Pi which acts as a base station. The Arduino consist of analog interface pins from A0- A7. The sensors having analog output are usually interfaced with the Arduino nano analog pins. The output from the sensor node can also be compared with the voltage that can be given to analog Ref pin. The output coming from sensor nodes can also be monitored on serial monitor provided by Arduino programming. Arduino is widely used open-source hardware and software platform for developing WSN resulting into cheap, low power standard and most flexible system employ with wireless monitoring (Deshmukh and Shinde 2016). MQ-135 is air pollution gas sensor interfaced with Arduino uno, so as DHT11 temperature and humidity sensor is interfaced with Raspberry pi 3 along with HW-611 e/p 280 atmospheric pressure detection sensor (Singh et al. 2020). The problem with MQ135 sensor is that specifically it cannot tell the Carbon Monoxide or Carbon Dioxide level in the atmosphere, but the pros of MQ135 is that it is able to detect smoke, CO, CO2, NH4 and we have used CO (Carbon Monoxide) MQ7 sensor (Sai et al. 2019). MQ135 and DHT22 are used to sense CO_2, temperature, humidity, and heat index respectively. Data will be sent periodically to a web server using ESP8266 Wi-Fi module through secure HTTPS POST protocol. On the back-end side, a web server is employed to receive sensor parameters as well as to build a website application securely by which users can monitor it remotely (Septian et al. 2022).

Current low-cost particle sensors based on light-scattering, however, are vulnerable to airflow disturbance on moving vehicles. In order to address this problem, here build air quality monitoring nodes, Mosaic-Nodes, with a novel constructive airflow-disturbance design based on a carefully tuned airflow structure and a GPS-assisted filtering method. Further, the buses used for system deployment are selected by a novel algorithm which achieves both high coverage and low computation overhead. The collected sensor data is also used to calculate the $PM_{2.5}$ of locations without direct measurements by an existing inference model (Gao et al. 2016). But the most important step is to calibrate the sensor in fresh air and then draws an equation that converts the sensor output voltage value into our convenient units PPM (Sai et al. 2019). The key goal was to create an air quality monitoring device that was both portable and easy to install. The number of people using Android devices and accessing the internet has skyrocketed. The device's outcome can be made simple for users be seen in a website as well as in android app. It would be extremely beneficial to human health if pollution levels were measured in the areas of air in everyday life. Different types of pollution monitoring gas sensors will be deployed in various locations throughout the city to detect air pollution. The contaminated areas will be given top priority polluted area and the area that contains harmful particles to human. These sensors will collect practical data in real time from different affected areas on different gases which are present in the environment e.g., nitrogen dioxide (NO2), smoke, benzene, LPG gas, carbon monoxide (CO), methane (CH4) and humidity. And the application of device that delivers a signal when polluted nature exceeds allowed limits.

3. Methodology

In this research, various sensors are used to identify humidity, environment temperature, atmospheric pressure and Carbon dioxide gas (CO2), nitrogen dioxide (NO2), smoke, benzene, LPG gas, carbon monoxide (CO) and methane (CH4) present in the air. Arduino UNO is boards used in interfacing above mentioned sensors. MQ-2 for methane, butane, LPG, MQ-4 for CNG, MQ-7 for Carbon Monoxide and MQ-135 are Benzene, alcohol, smoke gas sensor interfaced with Arduino UNO, and here DHT22 act as temperature and humidity sensor. Atmospheric pressure sensor detects air pressure with humidity and temperature the result obtained will automatically get feed in our devise. After wards it can read our derived value on IOT. To run Arduino UNO board, we have used Arduino IDE software application. Arduino IDE software is an open-source software application that makes easy code writing, compiling and then it uploads the code on the basis of circuitry designed in board. We have used here blue serial beta app for connecting an android device to a serial Bluetooth enabled device and monitor overall air quality monitoring system. Figure 1 demonstrates the complete flowchart of the proposed methodology and can be explained with 5 steps.

Figure 1. The Flowchart of the Proposed Methodology

3.1 Analysis of standard air composition

Many substances can be found in the air. Nitrogen (78.08 %), oxygen (20.95 %), argon (1.2 %), carbon dioxide (0.04 %), and water vapor make up the atmospheric composition (Table 1 and Figure 2). There are a few additional gases in the air, but they only make up a very small percentage of the total (Haynes et al. 2016).

Water vapor: It is well known that water in lakes and rivers evaporates and flows into the air throughout the summer. As a result, water vapor is one of the air's ingredients. This uses a lot less of the planet's atmosphere.

Nitrogen: When we puff over a blazing candle, nitrogen extinguishes. It means that non-combustible gases are frequently present in the air (gases that do not help combustion). This is primarily due to nitrogen concentrations. Nitrogen is the most prevalent substance on our planet, accounting for roughly 78.08% of the atmosphere.

Carbon dioxide: Carbon dioxide is primarily produced by plant and animal respiration as well as fuel combustion. This represents 0.04 % of the earth's environment. Our atlas' presence continues to shift from one region to the next. Particles of smoke and dust: Due to combustion of oils, smoke is present in huge amount in our environment. The occupation ranges from one location to another. It is a gas mixture that is therefore baneful. Besides these, weal so detect dust particles in our milieu when we see a beam of light in a dark space. Smoke and dust particles constitute less than 1% of earth's atmosphere (Shilton, N. 2003).

Table 1. Standard Composition of Air

Name of Gases	% By Volume	% By Weight	Parts per Million (% By Volume)	Chemical Symbol	Molecular weight
Nitrogen	78.08	75.47	780790	N2	28.01
Oxygen	20.95	23.2	209445	O2	32
Argon	0.93	1.28	9339	Ar	39.95
Carbon Dioxide	0.04	.062	404	CO2	44.01
Neon	.0018	.00123	18.21	Ne	20.18
Helium	.0005	.00007	5.24	He	4
Krypton	.0001	.0003	1.14	Kr	83.8
Hydrogen	.00005	Negligible	.5	H2	2.02

Xenon	.0000087	.00004	.087	Xe	131.3

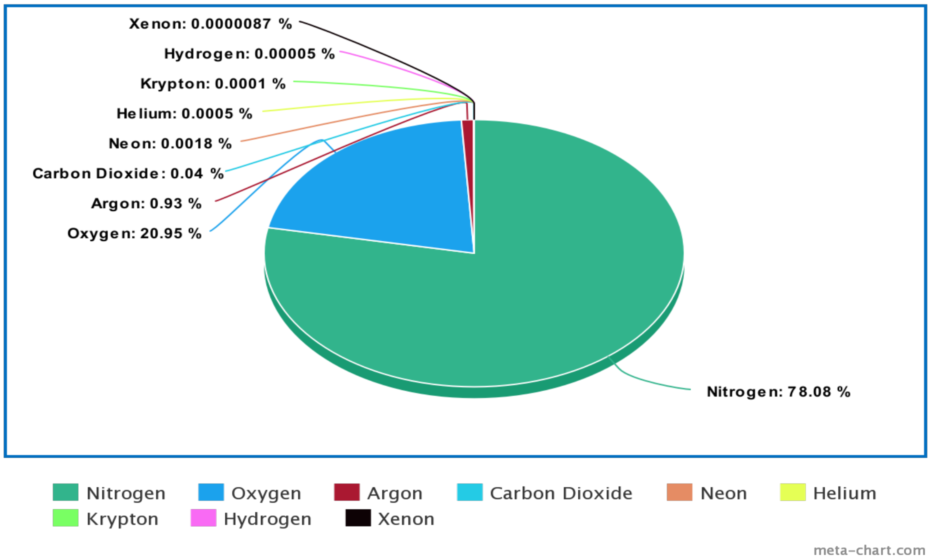

Figure 2. Standard Composition of Air

3.2 Analysis of Air Quality Index (AQI)

An air quality index (AQI) is a figure used by government agencies to inform the public about how contaminated the air is now or will become in the future. As the AQI rises, a growing percentage of the population is likely to suffer from progressively severe health consequences. Distinct countries have different air quality indexes that correspond to different levels of pollution (Kumari and Jain 2018). Many components in the air can become toxic and damaging to humans when their numbers increase. For the objectives of our research, we have studied many elements such as CO2, CO, LPG, CH4 and so on. They have the potential to cause serious harm to humans if their numbers are greatly expanded. The AQI's purpose is to help you realize the meaning of local air quality for your health. The AQI is divided into six categories in order to make it comprehensible to realize that shown in Table 2.

Table 2. Air Quality Index (AQI) with colors

Air Quality Index	Levels of Health Concern	Colors
0 to 50	Good	Green
51 to 100	Moderate	Yellow
101 to 150	Unhealthy for sensitive Groups	Orange
151 to 200	Unhealthy	Red
201 to 300	Very Unhealthy	Purple
301 to 500	Hazardous	Maroon

Each category relates to a distinguished level of health concern. The six levels of salubrious concern and what they mean are:

"Good" AQI is 0 to 50. Air quality is regarded reasonable, and air contamination poses minuscule or no risk.

"Moderate" AQI is 51 to 100. Air quality is acceptable; however, for some contaminants there may be moderate health concern for a very tiny number of populous. For instance, people who are unusually susceptible to ozone may face respiratory symptoms.

"Unhealthy for Sensitive Groups " AQI is 101 to 150. Although general public's not likely to be affected at this AQI range, people with lung disease, older adults and children are at a greater risk from exposure to ozone, whereas persons with heart and lung disease, older adults and children are at greater risk from the presence of particles in the air.

"Unhealthy" AQI is 151 to 200. Everyone may begin to experience some negative health effects, and members of the sensitive groups may face more dangerous effects.
"Very Unhealthy" AQI is 201 to 300. This would cause a health alert resembling that everyone may experience more serious health effects.
"Hazardous" AQI greater than 300. This would trigger a health precautions of emergency situation. The entire population is more likely to be affected.

Air contamination is an urban smokestack belching black cloud. It's the smog that dims the horizon, collecting over some towns. It's an old car's smelly gasoline that highly absorbs oil. Air contamination may also be opaque. This may cause respiratory setbacks, cancer, or other dangerous health issues in people who do not know the possible dangers of the gasses or pollutants that are not visible in the air.

3.3 Hardware development

The framework for context awareness is used to structure the suggested monitoring system. We employ two systems to control and monitor the geo sensor network and air pollution: a sensor network control system and an air pollution monitoring system. The control system assists the operators in controlling the sensor network, such as changing the sample interval and checking the network status. The operators are useful for keeping the good status of data transmission in geo sensor network.

The air pollution monitoring system supports sensor data abstraction and air pollution prevention models for understanding the pollution level and area. The models (Figure 3) are used for providing short message and safety alarm for people in pollution area.

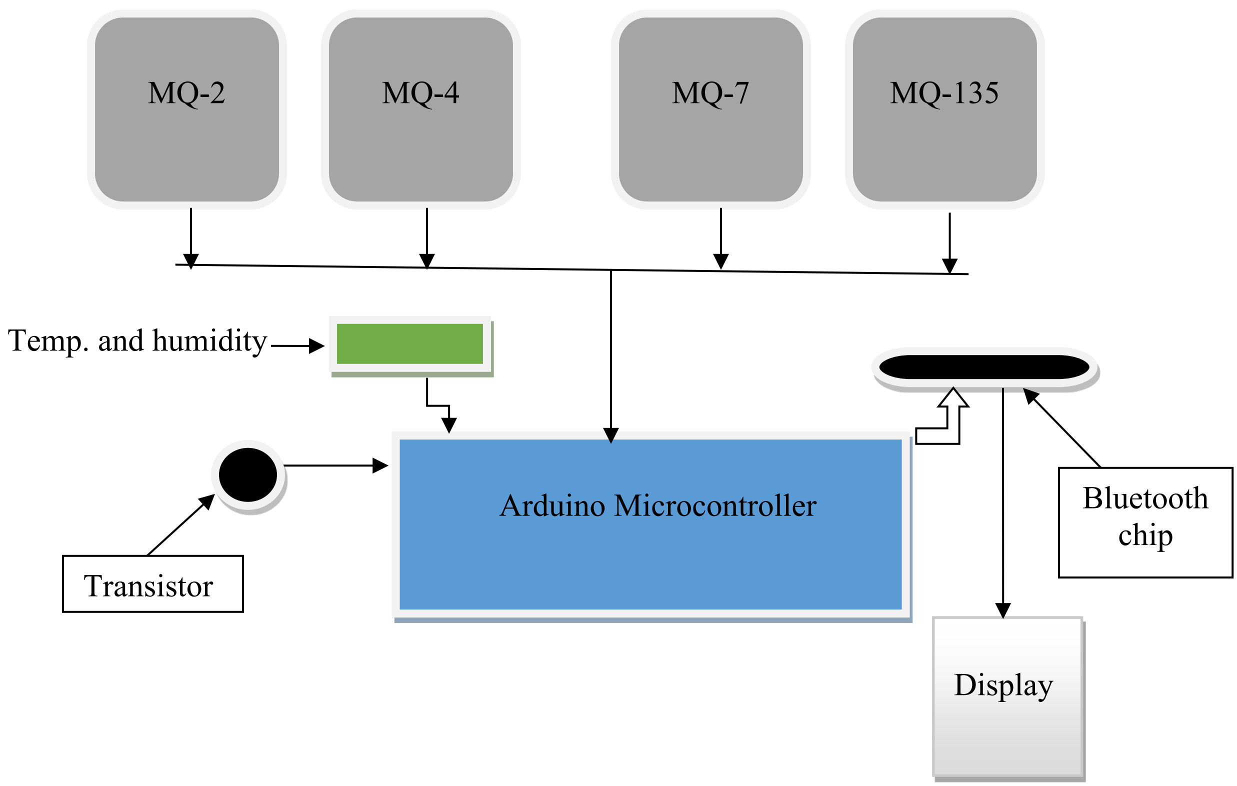

Figure 3. Air quality monitoring device model with several sensor

Air quality monitoring systems (AQMS) are divided into two categories: indoor and outdoor pollution monitoring, depending on the location of the event. The term "outdoor air pollution" refers to pollution in the open air and in the industrial environment. The indoor situation, on the other hand, is air pollution in small restricted, closed spaces, here indoor indicates internal environment of a garments industry.

Indoor and outdoor air monitoring systems have varied needs due to their diverse environments and pollutant kinds, as shown in Table 3.

Table 3. Comparing pollutant contaminants with different area

System Area	Deployment & maintains	Cost	Accuracy	Power Consumption	Response Time
Indoor (Garments industry)	Easy	Little	Average	Low	Average
Outdoor	Average	Average	High	Little	Average
Industrial	Average	Average	Very High	Average	Fast

In hardware development section the user design is created based on requirements collected data. In this phase, model and prototype that represent all system processes including inputs and outputs are developed. In this detailed user design includes how the system's flow, from beginning until the end, how this system working and how the systems architecture looks like that is shown by figure 4. This phase enables users to see to general flow of the system, understand the process flow and modify the working model of the system that meets their needs.

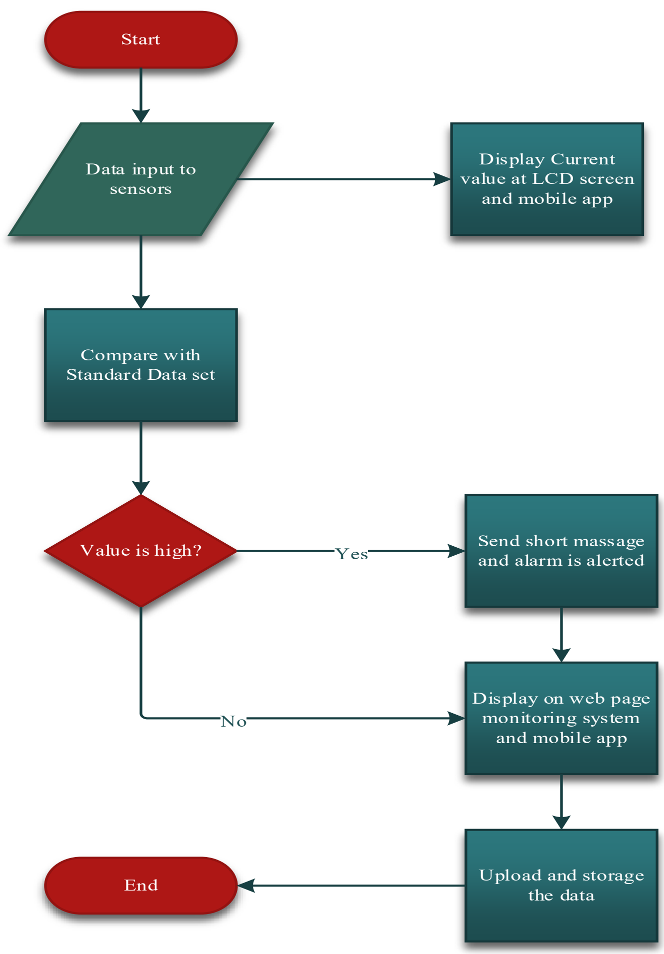

Figure 4. Detail user design flow Chart of the Proposed System

3.4 Arduino Programming

Before beginning the coding for this work, we need to first calibrate all the MQ gas and humidity sensor. There are lots of calculation involved in converting the output of sensor into PPM value. Here we have used different library for different sensor. In the code, first of all we have defined the libraries and LCD. By using the software serial library. We have made digital pin as TX and RX. Then we have included the library for the LCD and have defined the pins for the same and we also defined two more variables one for sensor and other for air quality value storing.

3.5 Data Pulling by using Blue serial beta app

In this research work, all real time data are pulling by using blue serial beta app that's are shown in figure 5. Here we have used observational method for our data collection in different area such indoor (Garments industry), outdoor and industrial area. After collecting all real time data then we have compared and analysis this data with standard data value and after that we have got the final outcome and result of our research.

Figure 5. Sample data collection and monitoring by using Blue serial beta app

4. Result and Discussion

The research objectives were to determine the possible the number of gases detected and motoring to minimize the health hazard mainly in industrial area in Dhaka and Gazipur city. The research works setting was created to investigate a human health issue using data collected from numerous MQ gas sensors, humidity sensor and temperature sensor. There are three types of section data measures. Indoor measurements differ slightly from typical data collection. In the steel industry, however, value changes mildly to 25% and dramatically to 147 percent. As a result, the amount of smoke, LPG, CH4, and butane is rising. In the construction sites, values have increased by 78%, while in the steel industry, they have increased by 262.35%. The level of methene construction site is increasing and in the same way, the value of other gases is highest in the steel industry.

If we consider the MQ-2 gas sensor, its specially measured smoke, LPG, CH_4, and butane where standard data are minimum 66 ppm and maximum 466 whereas other indoor and outdoor minimum and maximum value are:
Indoor minimum and maximum value are- 66-466ppm
Outdoor construction site minimum and maximum value are-192-457ppm
But we found the concentration of air is outdoor Steel industry min and max value are: 372 -772ppm, this value is very high and harmful for human body and our environment which is shown by figure 6.

Then if we consider MQ-4 gas sensor it also measures methane and CNG gas and it collect value several place as well as different industrial area in Gazipur. Whereas other indoor and outdoor minimum and maximum value are –
Indoor minimum and maximum value are: 36-93ppm
Outdoor construction site minimum and maximum value are- 87-259ppm
Outdoor Steel industry min and max value are: 337-518ppm

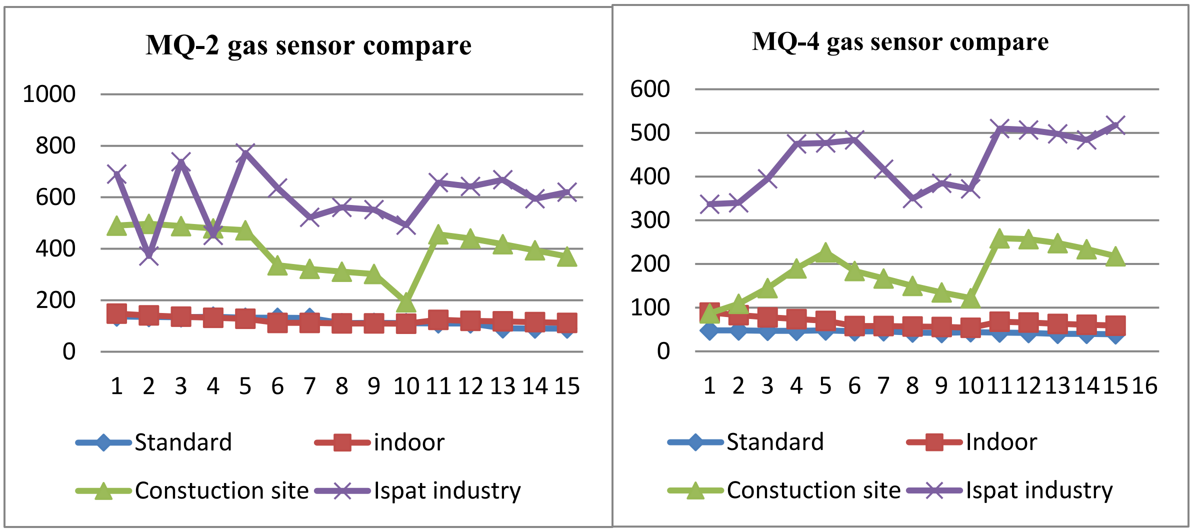

Figure 6. Compare different value of MQ-2 and MQ-4 sensor

Then if we consider MQ-7 gas sensor it measures CO gas. Whereas other indoor and outdoor minimum and maximum value are –
Indoor minimum and maximum value are 85-234ppm
Outdoor construction site minimum and maximum value are 107-432ppm
Outdoor Steel industry min and max value is 307-666pp
Similarly, if we consider MQ-135 gas sensor it measures air quality (benzene, alcohol, smoke, CO, ammonia). whereas other indoor and outdoor minimum and maximum value are:
Indoor minimum and maximum value are 72-301ppm
Outdoor construction site minimum and maximum value is 103-458ppm
Outdoor Steel industry min and max value is 301-708ppm

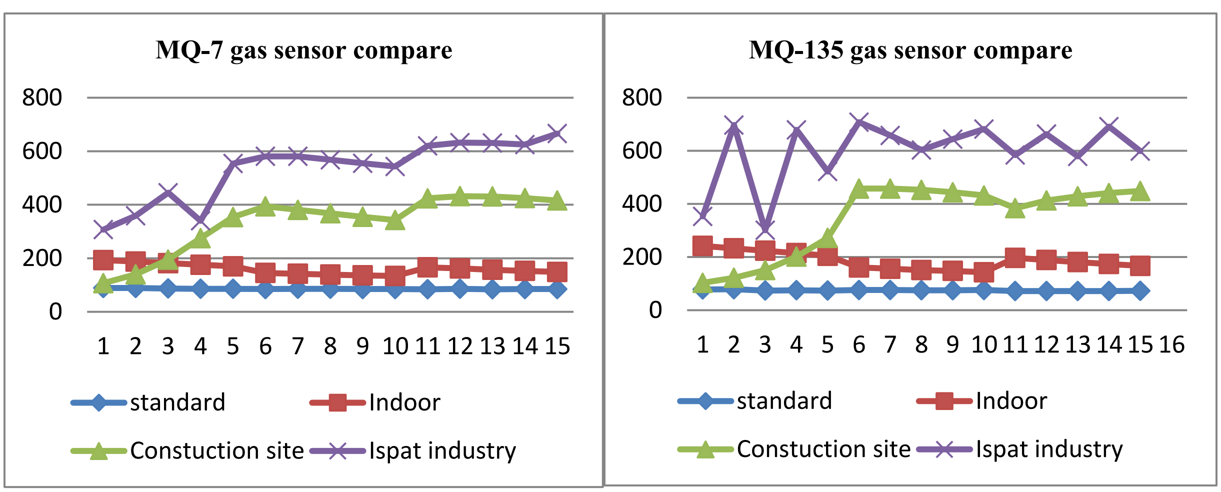

Figure 7. Compare different value of MQ-7 and MQ-135 sensor

The figure 7 show the difference between MQ-7 and MQ-135 sensor. The figure 8, shown the indoor air quality monitoring for garments industry and Outdoor air quality monitoring for construction sites After collecting air standard data we compute a data for indoor space. Here, Indoor indicates the air quality of a garments industry and outdoor indicates air quality of construction sites. In garments industry the pattern of air quality is similar and stable. On the other hand, the air quality of construction sites in very unstable and overall air quality is very harmful then air quality of garments industry.

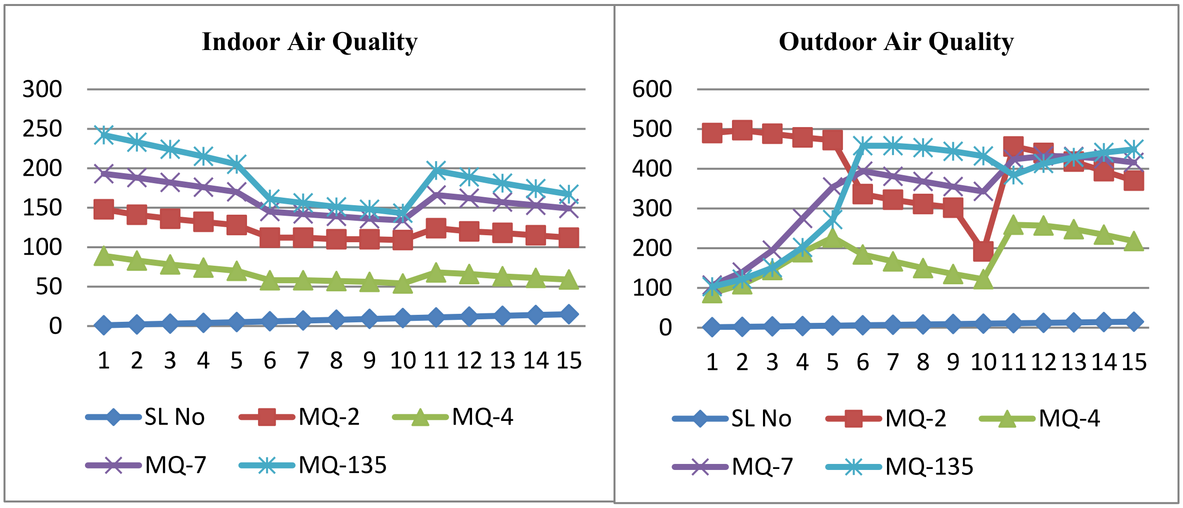

Figure 8. Indoor air quality monitoring for garments industry and Outdoor air quality monitoring for construction sites

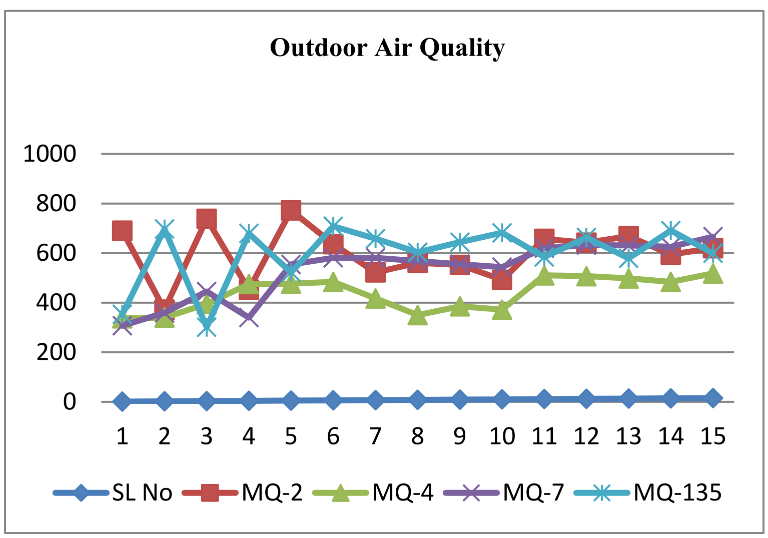

Figure 9. Outdoor air quality monitoring in Steel industry

The figure 9, shown the outdoor air quality monitoring in Steel industry, the graph shown the quality of air more unstable and harmful than others. Here MQ-2 sensor sensing maximum 800 ppm and overall range was found between 250 to 800ppm that's are very harmful for our human health.

5. Conclusion

This research proposed a low cost, low power, compact and highly accurate a smart IoT based air quality monitoring system that constantly keeps track of air quality in an area and displays the air quality measured on an LCD screen which integrates Bluetooth Modules, air quality sensor and Arduino Uno to form the Internet of Things (IoT)-based system. The system detects air pollutant emissions by using a gas sensor, MQ-2, MQ-4, MQ-7, MQ-135 which is capable of detecting 8 kinds of gas compounds which save 1/8 of power consumption of the node compared to using multiple sensors per pollutant. This system also, measured the effect of temperature and current temperature using DHT-11. With the help of DHT-11 sensor it can detected humidity present in the environment is also measured and monitored. It also sends data measured to the blue beta serial app by Bluetooth connection. All data were treated using a developed Arduino -based program. The system's general functionality was confirmed through a series of carbon monoxide and smoke level testing, which included tests in a normal or clean environment, building sites, the steel industry, and automotive indoor emissions at various time intervals. Every result was also backed up by systematic data logging, which will come in handy during erroneous reading, troubleshooting, and calibration. If unhealthy air quality is detected in certain industrial area, it will alert both industrial area and authority through a short alert notification indicated using buzzer. This system has features for the people to monitor the amount of pollution on their mobile phones using the application. The system helps to monitoring air quality and create awareness of the quality of air to everyone.

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