IoT Based Air Quality Monitoring System

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A thesis submitted in partial fulfillment of the requirements for the degree of Bachelor of Science in Computer Science and Engineering

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Declaration

We, hereby, declare that the work presented in this thesis is the outcome of the investigation performed by me under the supervision of Surajit Das Barman, Senior Lecturer, Department of Computer Science and engineering, East West University. We also declare that no part of this thesis has been or is being submitted elsewhere for the award of any degree or diploma.

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Letter of Acceptance

This thesis report entitled "IoT Based Air Quality Monitoring System" submitted by "Muktasib Un Nur" and "Abdur Rahman" to the Department of Computer Science and Engineering, East West University is accepted by the department in partial fulfillment of requirements for the Award of the Degree of Bachelor of Science and Engineering on September, 2018.

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Abstract

Air pollution is one of the most concerning fact of today's world. Among all the man-made pollution, air pollution poses a serious threat for health. It affects human body through breathing and since this pollution is barely visible in eye, a monitoring system is necessary to stay cautious. This is the motivation behind our work so that government and citizens can stay aware of the air they are breathing.

Our objective is to provide a system to measure Air Quality and AQI level using gas sensors. We proposed a city model where the monitoring devices are connected through IoT technology. In the central based station, all the city data is stored and analyzed using classifier algorithm to predict future pollution of a city. From previous dataset we got high accuracy. Our work is significant for a city modeling where the authority wants a full monitoring on pollution and also the citizens want to stay concerned about the air quality.

The potential application of our work is for modern cities where pollution level is relatively higher. This system can directly impact on the city pollution control because when it is possible to monitor precisely, it is also possible to prevent pollution.

Acknowledgments

As it is true for everyone, we have also arrived at this point of achieving a goal in our life through various interactions with and help from other people. However, written words are often elusive and harbor diverse interpretations even in one's mother language. Therefore, we would not like to make efforts to find best words to express my thankfulness other than simply listing those people who have contributed to this thesis itself in an essential way. This work was carried out in the Department of Computer Science and Engineering at East West University, Bangladesh.

First of all, we would like to express my deepest gratitude to the almighty for His blessings on us. Next, our special thanks go to our supervisor, Surajit Das Barman, who gave us this opportunity, initiated us into the field of IoT, and without whom this work would not have been possible. His encouragements, visionaries and thoughtful comments and suggestions, unforgettable support at every stage of our BSc study were simply appreciating and essential. His ability to muddle us enough to finally answer our own question correctly is something valuable what we have learned and we would try to emulate, if we ever get the opportunity.

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There are numerous other people too who have shown me their constant support and friendship in various ways, directly or indirectly related to our academic life. We will remember them in our heart and hope to find a more appropriate place to acknowledge them in the future.

Muktasib Un Nur

September, 2018

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Chapter 1: Introduction

1.1. Introduction:

Among all the man-made environmental pollutions that takes place all over the world, air pollution is one of them. It is now the world's fourth-leading fatal health risk, according to the American Association for the Advancement of Science. Poor air quality in major cities can expose citizens to air pollution and lead to asthma attacks, lung cancer, heart disease or chronic bronchitis. For these reasons air quality represents a major challenge for governments and regulators alike. Indeed, earlier this year, 2018 the UK government found themselves in court over claims of failing to properly address levels of nitrogen dioxide in towns and cities [1]. To fight air pollution, air quality has to be measured accurately and a detailed model of the pollution detection system should be established in a country.

1.2 Monitoring Air Quality:

The AQI (Air Quality Index) is an index for reporting daily air quality [2]. It tells how clean or unhealthy the air is, and what associated health effects might be a concern. The AQI focuses on health effects people might experience within a few hours or days after breathing unhealthy air. The AQI is calculated for four major air pollutants regulated by the Clean Air Act: ground level ozone, particle pollution, carbon monoxide, and sulfur dioxide. The AQI has a scale that runs from 0 to 500. The higher the AQI value, the greater the level of air pollution and the greater the health concern. For example, an AQI value of 50 represents good air quality with little or no potential to affect public health, while an AQI value over 300 represents air quality so hazardous that everyone may experience serious effects. The purpose of the AQI is to help you understand what local air quality means to your health.

1.2.1 AQI Category:

To make it easier to understand, the AQI is divided into six levels of health concern [2]:

Air Quality Index Levels of Health Concern	Numerical Value	Meaning
Good	0 to 50	Air quality is considered satisfactory, and air pollution poses little or no risk.
Moderate	51 to 100	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.
Unhealthy for Sensitive Groups	101 to 150	Members of sensitive groups may experience health effects. The general public is not likely to be affected.
Unhealthy	151 to 200	Everyone may begin to experience health effects; members of sensitive groups may experience more serious health effects.
Very Unhealthy	201 to 300	Health alert: everyone may experience more serious health effects.
Hazardous	301 to 500	Health warnings of emergency conditions. The entire population is more likely to be affected.

Figure 1.1: AQI Category

Good:

The AQI value for an area is between 0 and 50. Air quality is satisfactory and poses little or no health risk.

Moderate:

The AQI is between 51 and 100. Air quality is acceptable; however, pollution in this range may pose a moderate health concern for a very small number of individuals. People who are unusually sensitive to ozone or particle pollution may experience respiratory symptoms.

Unhealthy for Sensitive Groups:

When AQI values are between 101 and 150, members of sensitive groups may experience health effects, but the general public is unlikely to be affected.

Unhealthy:

Everyone may begin to experience health effects when AQI values are between 151 and 200. Members of sensitive groups may experience more serious health effects.

Very Unhealthy:

AQI values between 201 and 300 trigger a health alert, meaning everyone may experience more serious health effects.

Hazardous:

AQI values over 300 trigger health warnings of emergency conditions. The entire population is even more likely to be affected by serious health effects.

Each day, monitors record concentrations of the major pollutants at more than a thousand locations across the country. These raw measurements are converted into a separate AQI value for each pollutant (ground-level ozone, particle pollution, carbon monoxide, and sulfur dioxide) using standard formulas developed by EPA. The highest of these AQI values is reported as the AQI value for that day.

1.2.2. AQI for different gas:

Each of the 6 gases has their own scale for AQI. These scales define how much concentration of that gas is acceptable to human body and which is dangerous [3].

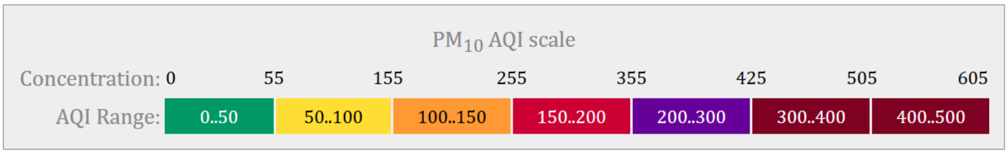

Figure 1.2: PM10 AQI Scale

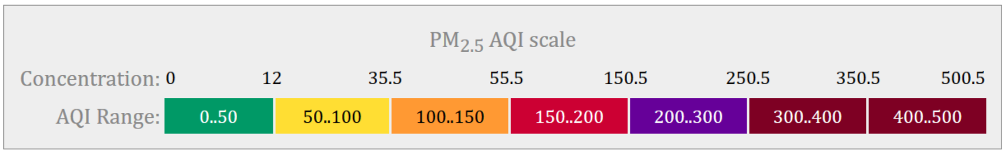

Figure 1.3: PM2.5 AQI Scale

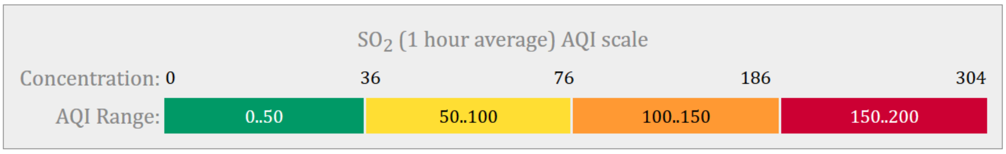

Figure 1.4: SO2 AQI Scale

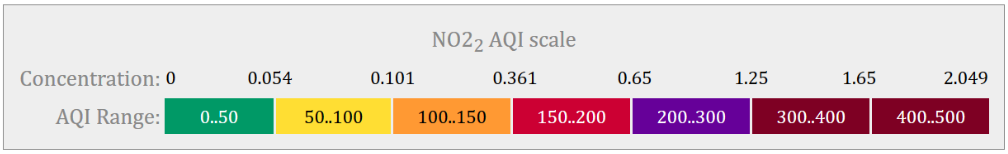

Figure 1.5: NO2 AQI Scale

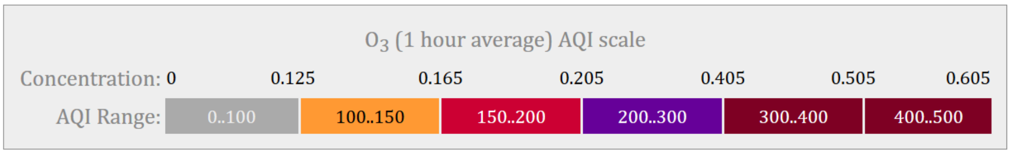

Figure 1.6: O3 AQI Scale

1.3 IoT:

The meaning of IoT is "Internet of things". IoT is an ecosystem of connected physical objects that are accessible through the internet. The 'thing' in IoT could be a person with a heart monitor or an automobile with built-in-sensors, that is the objects that have been assigned an IP address and have the ability to collect and transfer data over a network without manual assistance or intervention. These devices, or things, connect to the network to provide information they gather from the environment through sensors, or to allow other systems to reach out and act on the world through actuators. They could be connected versions of common objects you might already be familiar with, or new and purpose-built devices for functions not yet realized. They could be devices that you own personally and carry with you or keep in your home, or they could be embedded in factory equipment, or part of the fabric of the city you live in. Each of them is able to convert valuable information from the real world into digital data that provides increased visibility into how your users interact with your products, services, or applications. In particular, “things” might communicate autonomously with other things and other devices, such as sensors in manufacturing environments or an activity tracker with a smartphone. A network of intelligent devices and grid infrastructure will be largely based on IoT concepts. The smart grid will be implemented on a type of “internet” in which every energy packet is managed in a similar fashion to a data packet, across routers and gateways that can autonomously decide the best pathway for the packet to reach its destination, based on standard and interoperable communication transceivers, gateways and protocols [4].

In a nutshell, the Internet of Things is the concept of connecting any device to the Internet and to other connected devices. The IoT is a giant network of connected things and people – all of which collect and share data about the way they are used and about the environment around them.

1.4 IoT based air quality solution:

A particularly challenging part of air quality control is accurate monitoring. In many cities, the air quality monitoring infrastructure is limited to large, fixed monitoring stations, making it difficult for experts to accurately gauge the levels of air pollution in their cities and its impact on citizens' lives. The development of the Internet of Things (IoT) has the potential to change this situation Advances in low power wide area (LPWA) networks have led to the availability of small, portable, low cost, and always connected sensors. With low data rates and long reach, LPWA sensors can be attached to street furniture, bicycles or even people, to measure and report air quality with more regularity and precision than ever before. Big data capabilities, such as analytics and machine learning, can then be applied to these measurements and related data sets, such as weather and traffic, to add context to the data and understand the causes and fluctuations in air pollution levels.

Whilst not intended to fully replace established monitoring networks, governments across the world are investing huge sums in policies and partnerships to explore IoT driven air quality solutions. Chongqing City in China for example, is currently working with China Mobile to explore how connected sensors could improve their air quality monitoring, while Telefonica and Orange are working with cities in France, Spain, Portugal and Brazil in much the same vain [5]

1.5 Problem Statement:

Air pollution is a vital issue for a country. An air polluted country falls prey to many different environmental issues and health hazards. Recently in Bangladesh there are various debatable and questionable conditions arises when it comes to air pollution, cause, from different foreign surveys it is found that, the air quality in Bangladesh is very hazardous and it is one of the worsts in the world ranking [6]. In 2002, continuous air quality monitoring was commenced through the establishment of Continuous Air quality Monitoring Station (CAMS) by Department of Environment (DoE) under the world bank financed Air Quality Management Project (AQMP) [7]. But in there is no organization or any government projects that works in detail on air pollution and air quality. There are some International websites where they display the live air quality and unfortunately, they don't have enough data about Bangladesh's air quality in their database. For Bangladesh, the AQI measured by US embassy is followed widely. But problem remains about the accuracy because the measurement device is installed on the premise of US embassy and it can only detect quality of the surrounding air. This value cannot represent the AQI for all the cities, even the other part of Dhaka city.

- The main goal of our thesis work is to detect the gases responsible for air pollution and measure the air quality and view the pollution level so that we can evaluate which gases are responsible for pollution in which area the most and in which rate the air is being affected.

1.5.1 Reason for choosing CO:

Carbon monoxide poisoning occurs when carbon monoxide builds up in our bloodstream. When too much carbon monoxide is in the air, human body replaces the oxygen in red blood cells with carbon monoxide. This can lead to serious tissue damage, or even death. Carbon monoxide is a colorless, odorless, tasteless gas produced by burning gasoline, wood, propane, charcoal or other fuel [8].

The reason we chose CO in our system is the danger of its very little concentration. Where 100-200 ppm is tolerable for other gases, only 10ppm of CO can cause a very high level of health risk.

1.5.2 Effects of CO in human body:

Carbon Monoxide have serious effect on all aged person. Depending on the degree and length of exposure, carbon monoxide poisoning can cause permanent brain damage, damage to our heart, possibly leading to life-threatening cardiac complications, fetal death or miscarriage [9].

Unborn babies:

Unborn babies are at the highest risk of carbon monoxide poisoning, because fetal hemoglobin mixes more readily with CO than adult hemoglobin; therefore, the baby's carbon monoxide levels become higher than the mother's. Babies and children whose organs are still maturing are at risk of permanent organ damage.

Children:

Young children and infants breathe faster than adults and have a higher metabolic rate, so they inhale up to twice as much air as adults, particularly when sleeping, heightening their exposure to carbon monoxide

Older adults:

Older people who experience carbon monoxide poisoning may be more likely to develop brain damage.

People who have chronic heart disease:

People with a history of anemia and breathing problems also are more likely to get sick from exposure to carbon monoxide.

Those in whom carbon monoxide poisoning leads to unconsciousness:

A person having Carbon Monoxide poisoning who loss of consciousness indicates more severe exposure.

Chronic Exposure:

Chronic exposure to carbon monoxide can have extremely serious long-term effects, depending on the extent of poisoning. The section of the brain known as the hippocampus is responsible for the formation of new memories and is particularly susceptible to damage. Up to 40% of people who have suffered from carbon monoxide poisoning experience problems such as amnesia, headaches, memory loss, personality and behavioral changes, loss of bladder and muscle control, and impaired vision and coordination. These effects do not always present themselves immediately and can occur several weeks or more after exposure. Whilst the majority of people suffering from long-term effects of carbon monoxide poisoning recover with time, some people suffer permanent effects, particularly when it comes to organ and brain damage [10].

Respiratory System:

The respiratory system struggles to distribute air around the body because carbon monoxide deprives the blood cells of oxygen. This results in shortness of breath, particularly when undertaking strenuous activities. Every-day physical and sporting activities will take more effort and leave you feeling more exhausted than usual. These effects can worsen over time as your body's power to obtain oxygen becomes increasingly compromised.

Both your heart and lungs are put under pressure as the levels of carbon monoxide increase in the body tissues. The heart will try harder to pump what it wrongly perceives to be oxygenated blood from your lungs to the rest of your body. As a result, the airways begin to swell causing even less air to enter the lungs. With long-term exposure, the lung tissue is eventually destroyed, resulting in cardiovascular problems and lung disease.

Nervous System:

Carbon monoxide can severely affect the central nervous system and people with cardiovascular disease. Carbon monoxide leaves the brain struggling for sufficient levels of oxygen and this in turn affects the heart, brain and central nervous system. As well as symptoms such as headaches, nausea, fatigue, memory loss and disorientation, increasing levels of CO in the body go on to cause lack of balance, heart problems, cerebral edemas, comas, convulsions and even death. Victims may experience rapid and irregular heartbeats, low blood pressure and arrhythmias of the heart. Cerebral edemas caused by carbon monoxide poisoning are particularly dangerous as they cause the brain cells to be crushed, affecting the whole nervous system.

1.6 Proposed model:

Our work demonstrates the model that will help the country in the long run to control Air pollution more efficiently. According to our model, the whole system will be connected through IoT technology. In every city, the devices will be established in particular area prone to pollution. Those devices are connected to a local base station. When each station in a city delivers data to the base station of that city and finally to the base station of that district it will cover that whole district. And by doing the same for the whole 64 districts and finally sending the data to the county's base station and analyzing it, we can determine which area of which district is the most polluted and similarly which district is more than which one and what gases are responsible for the pollution and then government can take necessary steps to reduce the pollution and take other steps for further preventions.

Those pollution data are also available for citizens to view. For every city, there is a channel number for the city base station. With a specific application, by using the channel number, citizens can also see the pollution level of their city and get concerned about health. According to the AQI level of the city they can take necessary caution to save themselves from pollution related diseases.

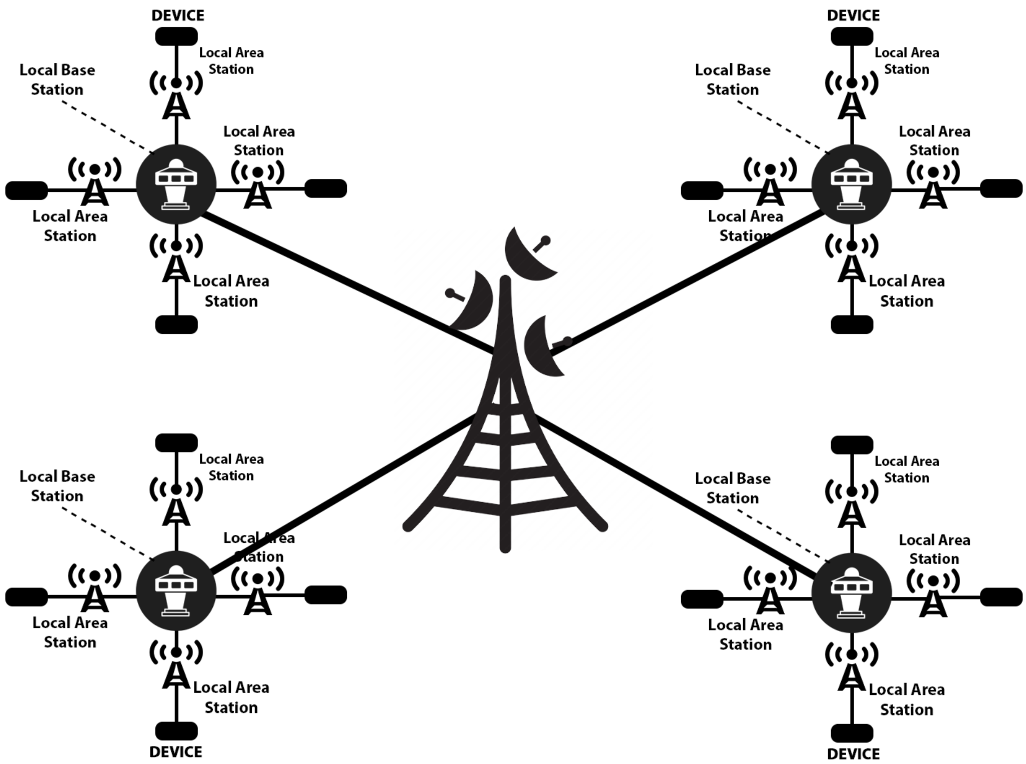

Figure 1.7: Our proposed model

1.7 Organization of this book:

In chapter 2 we have discussed about the works which are closely related to our topic. In Chapter 3 we have discussed the architecture of our device, implementation part and how we have done what we have done so far. In chapter 4 we have the result and experiment part of our thesis work. In chapter

5 we did some prediction analysis on an AQI dataset. And in chapter 5 we have given our plan to extend our thesis in future and concluded our work.

1.8 Conclusion

In this introductory chapter we focused on our interest in working with air pollution. We discussed about the facts regarding it and the index that is followed to measure pollution. Then we described our main goal and objective and our contribution in this book.

Chapter 2: Related Works

2.1 Introduction:

Among all the man-made environmental pollutions that takes place all over the world, air pollution is one of them. It is now the world's fourth-leading fatal

Nowadays, a lot of work has been going on the modern countries regarding air pollution. Countries are introducing more advance technologies to find the reasons behind it and ways to overcome air pollution.

2.2 State of the Art:

In this section, we have discussed other existing papers, books, journals that we have followed regarding our thesis work. These papers, books, and journals helped us to evaluate our thesis work in the right direction.

2.2.1 Existing Air quality monitoring system and their technology

2.2.1.01 US Embassy AQMP.

As we discussed earlier in section 1.4, some major countries have different parameters to detect air pollution and they have different AQI charts to follow. However, the AQ index by US embassy is the most widely used index throughout the world. Every US consulate in every country has their own device setup at the consulate premise to detect AQI level and show it to general people over their embassy website. As an example, in Bangladesh they only detect PM2.5 to measure AQI value [11].

Figure 2.1: US embassy AQMP in Bangladesh

2.2.1.02 Australian government AQMP

Australia uses a different scale and color code for AQI index which is given below. Australian government uses 3 different sites called Monash, Florey and Civic to detect Air Quality level where the established their pollution detection system [12]. In their system, they detect 5 of the toxic materials responsible for pollution – CO, O3, PM2.5, PM10, NO2.

Description	Air Quality Index	Description of Potential Health Risks
Very Good	0-33	Air quality is considered good, and air pollution poses little or no risk.
Good	34-66	Air quality is considered good, and air pollution poses little or no risk.
Fair	66-100	Air quality is acceptable. However, there may be a health concern for very sensitive people.
Poor	100-150	The air quality is unhealthy for sensitive groups, such as people with lung disease or heart disease. The general population is not likely to be affected.
Very Poor	150-200	Everyone may begin to experience health effects, especially those from sensitive groups.
Hazardous	200+	Everyone may experience health effects. In Canberra, the AQI only reaches this level during major bushfires or dust storms.

Figure 2.2: Australian scale

2.2.1.03 CAMS by DoE in Bangladesh:

In Dhaka monitoring of air quality data has a relatively short history. Only in 2002 continuous air quality monitoring was commenced through the establishment of Continuous Air quality Monitoring Station (CAMS) by Department of Environment (DoE) under the world bank financed Air Quality Management Project (AQMP) [7]. Before that, some uncoordinated efforts were undertaken by different authorities on intermittent or project basis. After the installation of CAMS at the premises of National Parliament it is now possible to have a better idea of the trends of air pollution in Dhaka city.

Department of Environment of Bangladesh has established CAMS in some places. The air quality data for Dhaka city from CAMS is available from 2002 only. Hence it is not possible to analyze the long-term trends of air pollution. But it still gives the opportunity to assess the variation in AQ due to the seasonal changes. Figure 2.5 shows the yearly average values of PM10 and PM2.5. It is seen from the graph that, yearly average values for PM10 shows an increasing trend. But PM2.5 concentrations show a trend which is slightly increasing. These imply that air pollution level in Dhaka city is increasing. It is also observed that these values are well above the World Health Organization (WHO) guidelines as well as exceed more the national standards of annual PM10 (50µg/m3) and PM2.5 (15µg/m3).

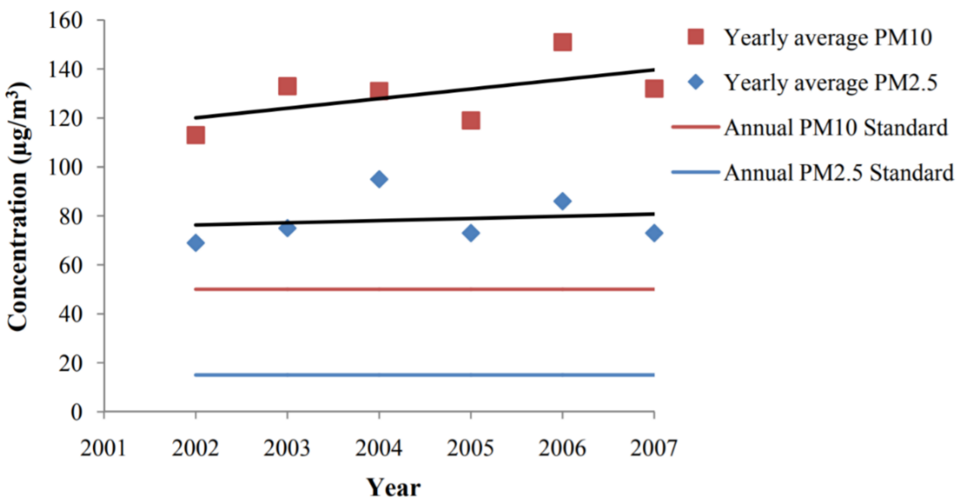

Figure 2.3: Variation of yearly average PM10 and PM2.5 (AQMP, 2007)

Figure 2.6 to Figure 2.11 shows the air quality recorded at the CAMS in Dhaka. From these graphs it is seen that mainly PM10 and PM2.5 values are well above the standard set by the DoE, Bangladesh during the dry season (November to March). During the wet season (April to October) ambient PM concentration comfortably meets the standard. These seasonal variations are seen in almost all the years for which data are available.

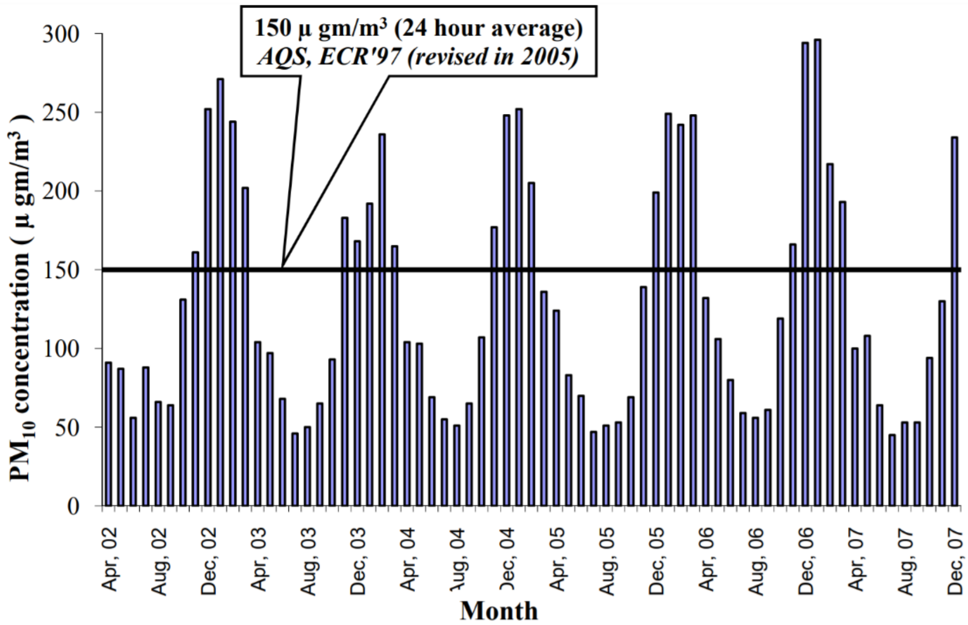

Figure 2.4: Monthly 24-hour average value of PM10 concentration (AQMP, 2007)

In addition, in some cases the concentration of Nitrogen oxides (NOx) has crossed the limit set by the ECR, 2005 (DoE, 2005). But the concentrations of

Carbon Mono-oxide (CO), Sulfer Di-oxide (SO2) and Ozone (O3) are well below the standard values. But these values also show the seasonal variation.

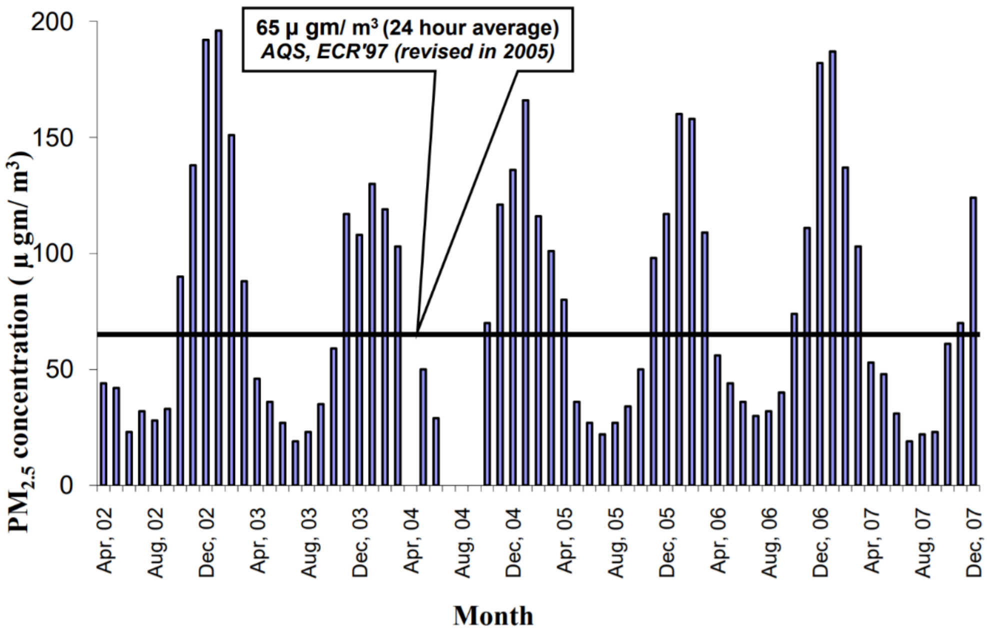

Figure 2.5: Monthly 24-hour average value of PM2.5 concentration (AQMP, 2007)

These seasonal variations are mainly due to the fact that, during the rainy days the wet depositions of different pollutants are effective. Especially the particulate matters are deposited to the ground, which results in lowering their ambient concentration.

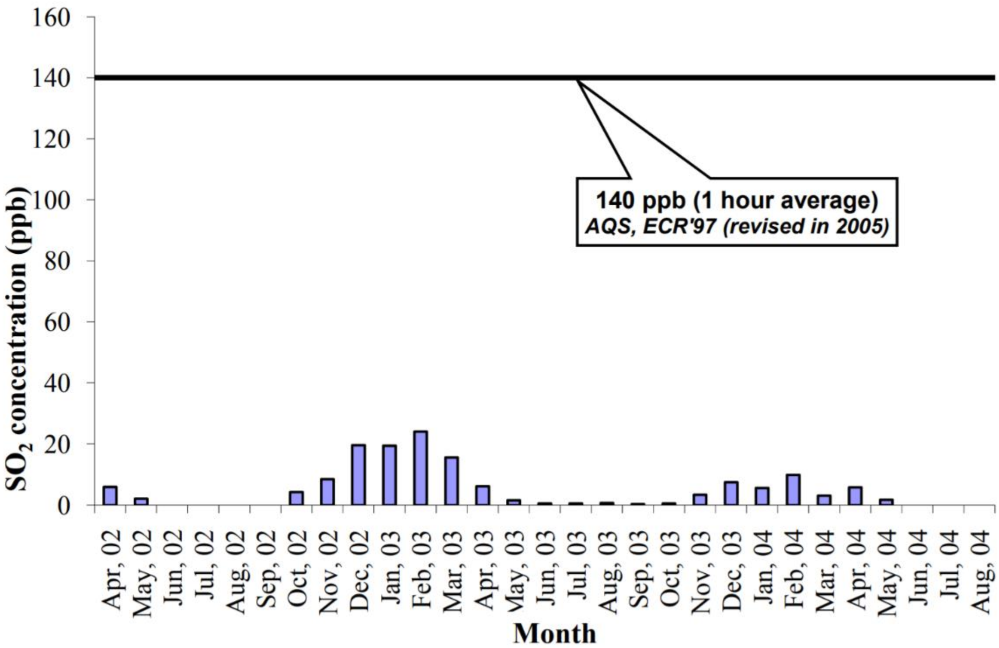

Figure 2.6: Monthly 24-hour average value of SO2 concentration (AQMP, 2007)

Moreover, during the entire dry season, the brick kilns around Dhaka remain operational, which increase the emission of pollutants and subsequently increases the ambient concentration in Dhaka city. These pollution charts show that the particulate pollution is the primary air pollution hazard in Dhaka city and the sources and distribution of particulates need to be studied further.

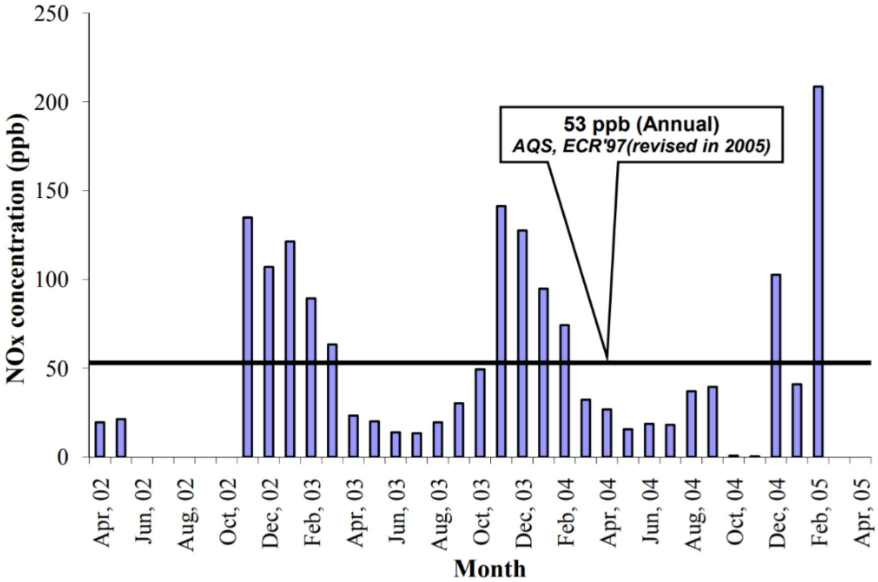

Figure 2.7: Monthly 24-hour average value of NOx concentration (AQMP, 2007)

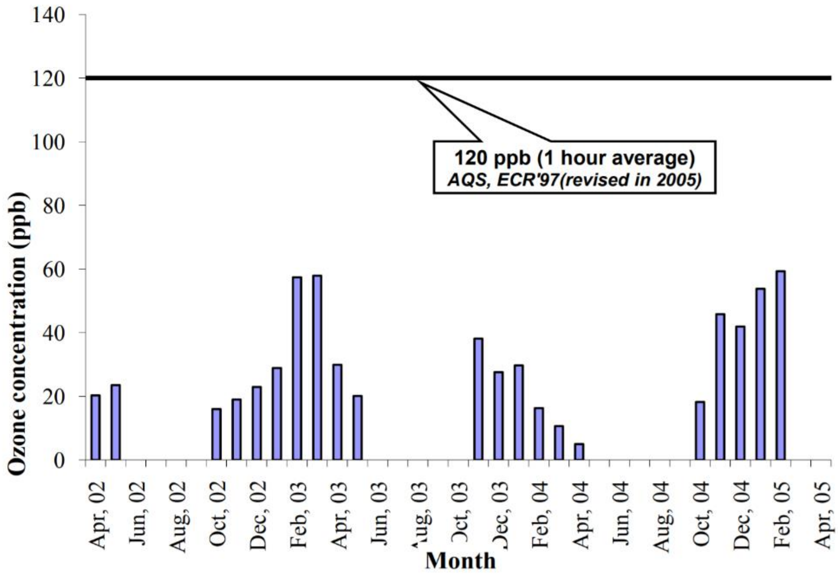

Figure 2.8: Monthly 1hour average value of O3 concentration (AQMP, 2007)

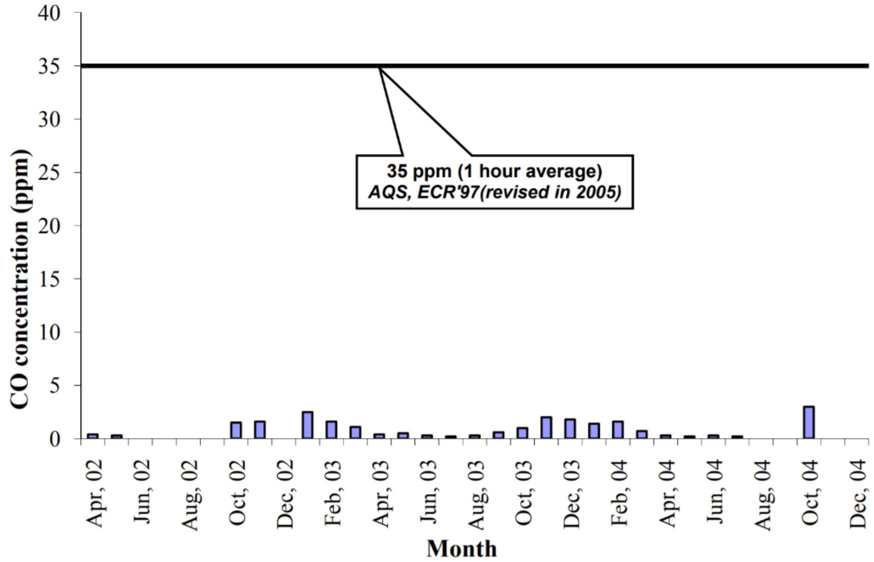

Figure 2.9: Monthly 1-hour average value of CO concentration (AQMP, 2007

2.2.2 International Literature Review:

In this paper [13], the authors have focused on the pollutions caused by the industrial activities. Here they have given a smart city model to monitor air pollution. They have established a wireless communication system through gas sensors on the busiest areas of the city. Where the sensors collect the pollution data from all the selected areas and stores them in a central database. They have mainly used 3 sensors which detects up to 14 gases. Every local area sensor collects data and stores them in the local database and then sends them to the server/central database. They have given a chart about some gases maximum allowable emission limits and from that chart they have used the threshold value and gave the prediction about pollution. In conclusion they said that their aim was to aid in reducing respiratory problems due to industrial activities. The papers main idea was to find out the increasing amount of harmful gases that caused air pollution and find particular solutions.

2.2.3 Local Literature Review:

In this paper [20], the authors concentrated on the PM10 and PM2.5 mainly. They also took some other gases to determine their pollution level. Those gases were Sox, NOx, COx and Ox. They run the CMAQ simulation in Dhaka city and found that 35% PM10 is associated with brick kiln and 15% PM2.5. As they worked around the brickfield mostly. And from the Continuous air monitoring station (CAMS) in the Shangshad Bhaban premises the Statistical Analysis Software (SAS) was used to determine significant levels of air pollution in Dhaka City. They run pairwise tests and from 36-pairwise comparisons, six of them were significant. And from the statistics of 2002-2010 they found that other than PM's the gases were equal to or less than the threshold values according to World Health Organization air quality guidelines. They found that from 2007-2009 it increased the most. And Nov-April of each year were responsible mostly for PM pollution from brick kiln.

2.3 Conclusion:

To conclude there are lot many works done by many international and local research. These works inspired us to generate ideas about our work.

Chapter 3: System Architecture and Implementation and Proposed System

3.1. Introduction:

In case of air pollution, AQI index is an important topic. We discussed broadly about AQI in section 1.2. To measure AQI level we need a properly designed device. We used Arduino Uno R3 to connect and control the sensors we used. In this section we are going to discuss briefly about those sensors and devices. We tried to measure AQI using Carbon Monoxide (CO) gas. Since all the gases which are responsible for air pollution has their AQI level, so measuring one gas gives us an AQI value.

3.2. Modules used:

3.2.1. Arduino:

Arduino Uno Rev 3 is a microcontroller board based on the ATmega328P [14]. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz quartz crystal, a USB connection, a power jack, an ICSP header and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started.

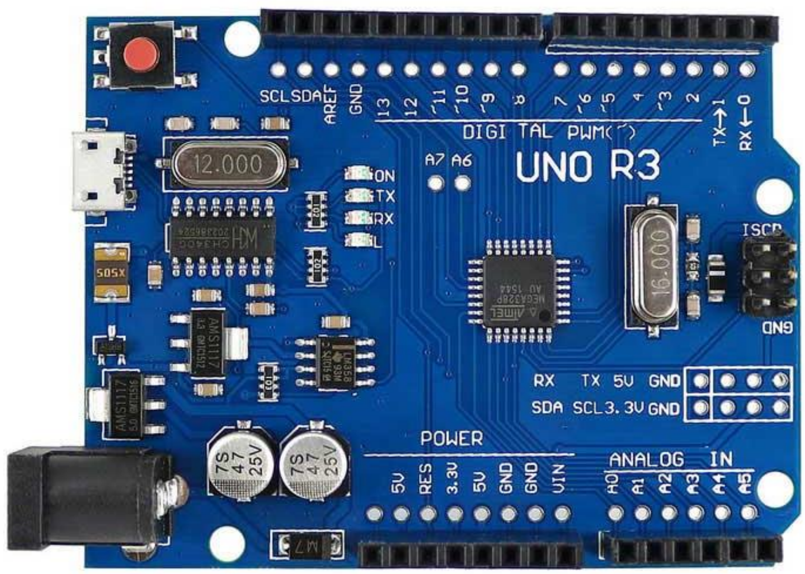

Figure 3.1: Arduino Uno Rev 3

3.2.2. Gas Sensor:

For sensing toxic gases, we used MQ groove series gas sensors [15]. The MQ series of gas sensors use a small heater inside with an electro-chemical sensor. They are sensitive for a range of gasses and are used indoors at room temperature. They can be calibrated more or less (see the section about "Load-resistor" and "Burn-in") but a known concentration of the measured gas or gasses is needed for that. The output is an analog signal and can be read with an analog input of the Arduino

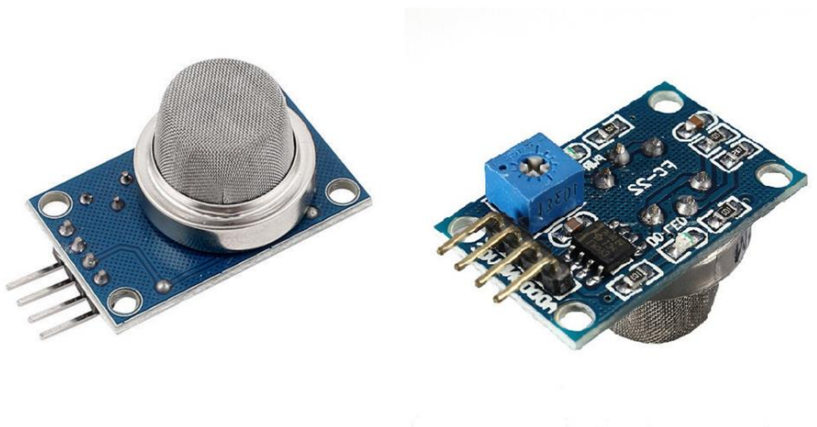

Figure 3.2: MQ Gas Sensors.

In the picture, the heater is for +5V and is connected to both 'A' pins. This is only possible if the heater needs a fixed +5V voltage. The variable resistor in the picture is the load-resistor and it can be used to determine a good value. A fixed resistor for the load-resistor is used in most cases. The Vout is connected to an analog input of the Arduino. The voltage for the internal heater is very important. Some sensors use 5V for the heater, others need 2V. The 2V can be created with a PWM signal, using analogWrite() and a transistor. Pre-heating is meant to make the sensor readings more consistent. A time of 12 or 24 hours is usually used for the burn-in time. Pre-heating is achieved by applying normal power to the sensor (to the heater and with the 'A' and 'B' pins connected, and with a load-resistor). In some special cases a specific burn-in is needed.

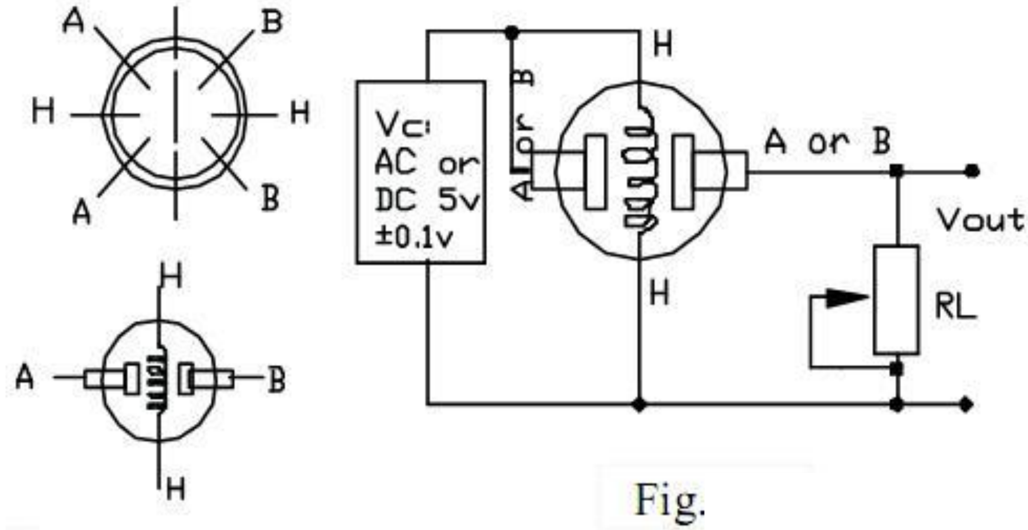

Figure 3.3: Circuit Design of MQ gas sensor.

For our system purpose we used 3 different MQ sensor's – MQ2, MQ9, MQ135. (MQ2) module is suitable for detecting H2, LPG, CH4, CO, Alcohol, Smoke or Propane [16]. Due to its high sensitivity and fast response time, measurement can be taken as soon as possible. MQ-9 gas sensor has high sensitivity to Carbon Monoxide, Methane and LPG. The sensor could be used to detect different gases contains CO and combustible gases. MQ135 gas sensor has high sensitivity to Ammonia (NH3), Sulfide and Benzene steam, also sensitive to smoke and other harmful gases. Every sensor has an Analog output. The output voltage from the Gas sensor increases when the concentration of gas increases. Sensitivity can be adjusted by rotating the potentiometer. From afterwards, we will mention them as Sensor 1, Sensor 2, Sensor 3 respectively.

3.2.3. Ethernet Shield:

The Arduino Ethernet Shield allows an Arduino board to connect to the internet [17]. It is based on the Wiznet W5100 ethernet chip (datasheet). The Wiznet W5100 provides a network (IP) stack capable of both TCP and UDP. It supports up to four simultaneous socket connections. The ethernet shield connects to an Arduino board using long wire-wrap headers which extend through the shield. This keeps the pin layout intact and allows another shield to be stacked on top. The shield provides a standard RJ45 ethernet jack. The reset button on the shield resets both the W5100 and the Arduino board. The shield contains a number of informational LEDs.

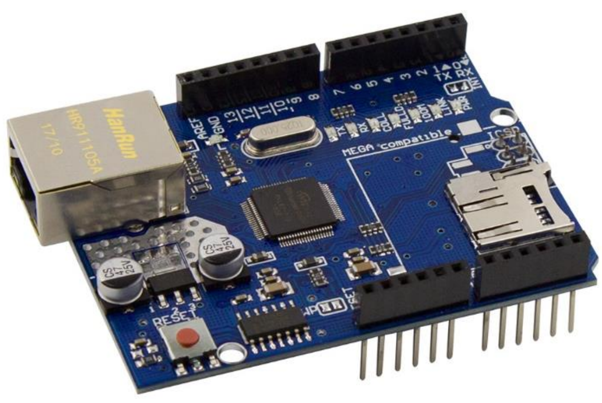

Figure 3.4: Arduino Ethernet Shield

3.3. Module connection:

To measure gas concentration in the air, we used Arduino microcontroller and 3 different gas sensors. The gas sensors are sensitive to particular gases. There is only one analog voltage we can get from the sensor.

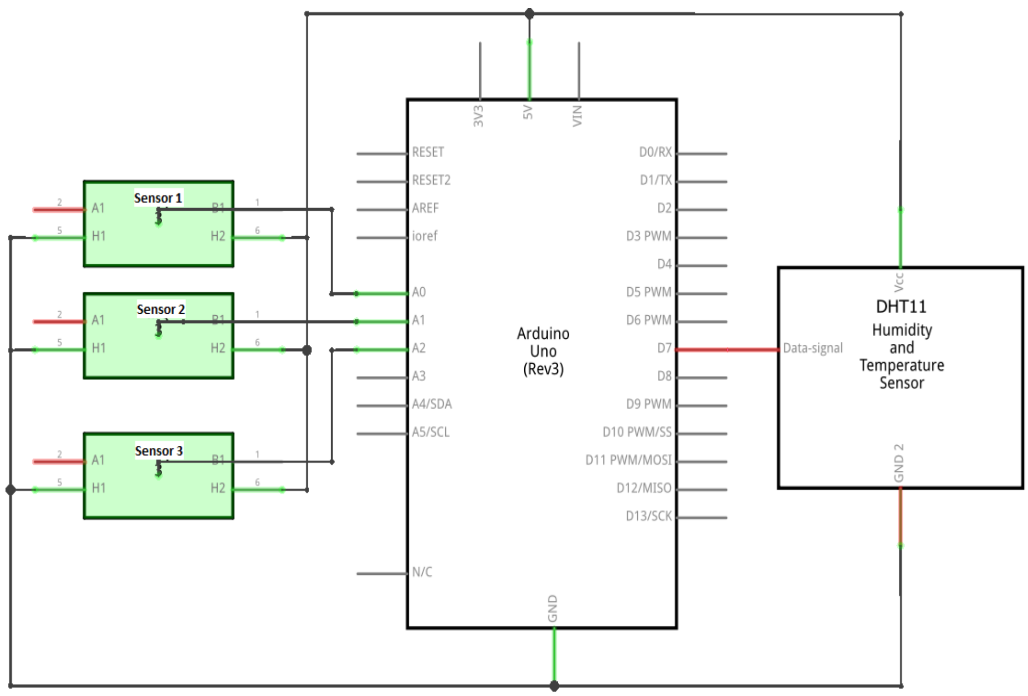

Figure 3.5: Pin Diagram of our device

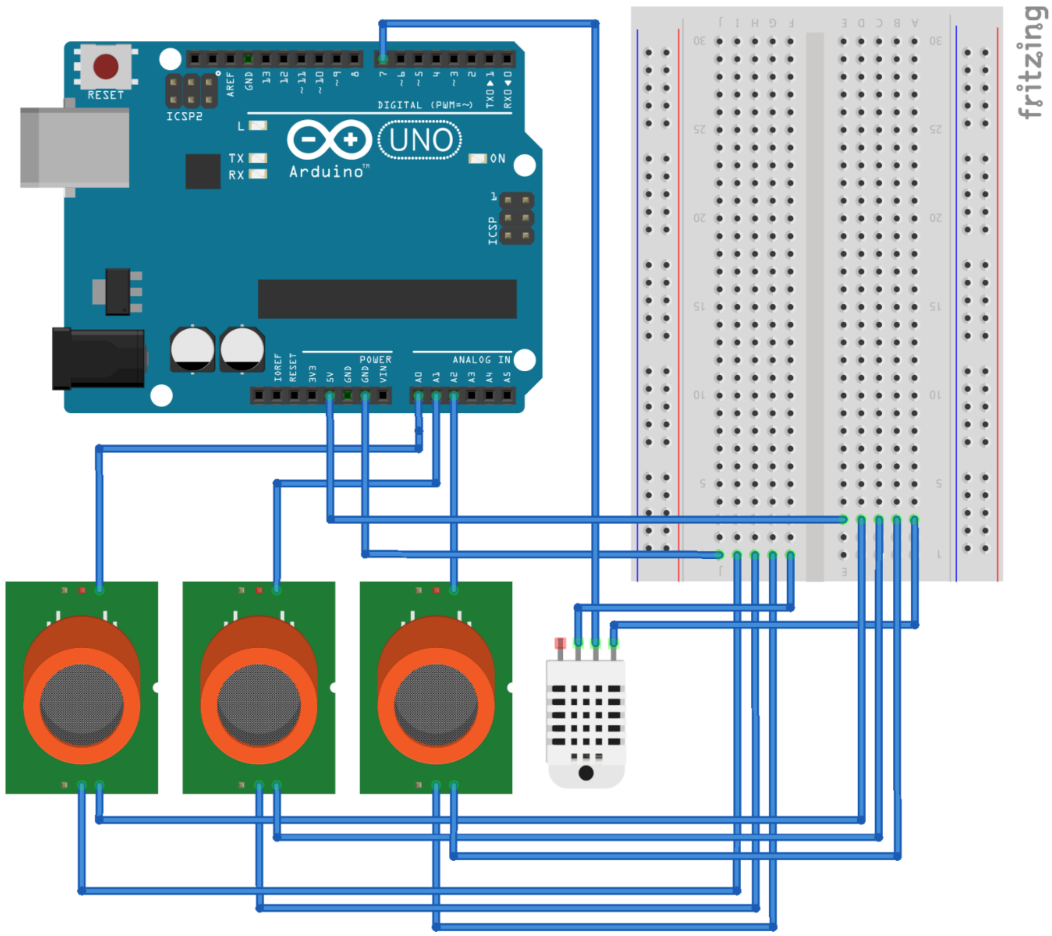

Figure 3.6: Circuit Diagram of our device

We used Arduino ethernet shield to upload sensor data in a cloud platform named ThingSpeak. Using the channel ID in ThingSpeak, anyone can see sensor data using internet from anywhere in the world.

3.4. Environment Setup:

To connect the whole device and make it functional, we need to connect the Arduino with a USB cable with a computer. Coding for the gas sensors and conditional decision making, we used Arduino Sketch IDE. After preparing the code, it can be compiled and uploaded to the Arduino. Before uploading, the proper Arduino board and COM port has to be selected from the menu of the IDE.

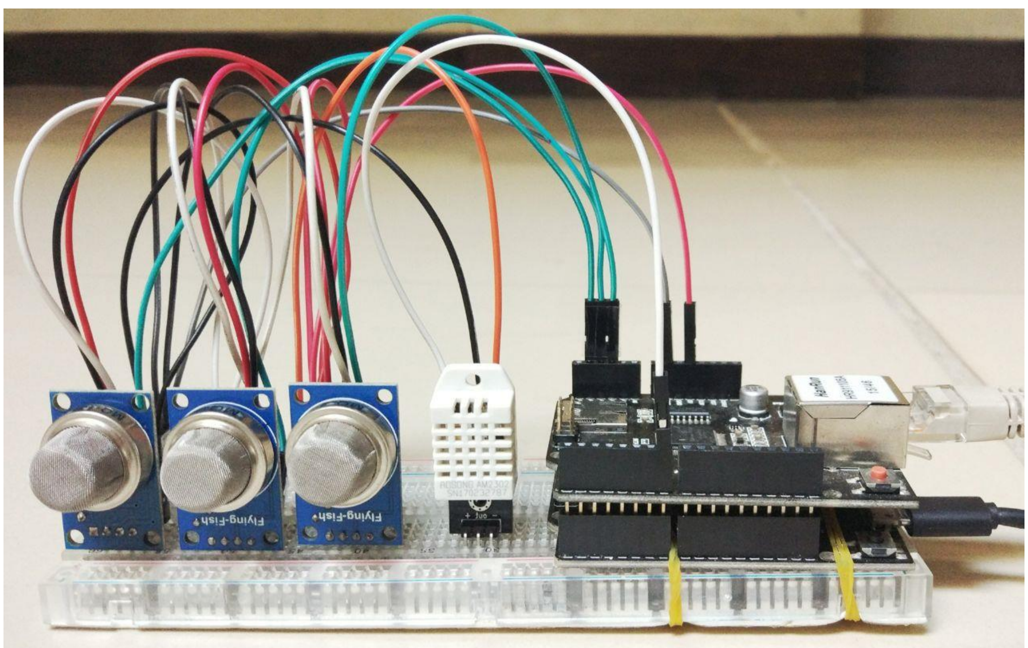

Figure 3.7: Actual look of our device

The Ethernet Shield which is stacked on the Arduino is connected to a router using a RJ45 straight-through cable. Using the router's internet connection, it will upload sensor data to a specific channel of ThingSpeak cloud platform. The channel Id and conditions for uploading to could are maintained inside the code.

After uploading the code, it takes several minutes to calibrate all the sensors. Then it starts to show the gas concentration in the serial port monitor of the IDE.

3.5. Problem Formulation and decision:

We considered CO to be our key to measure AQI. So, we are only going to discuss up to the point of measurement of CO concentration [18]. Consider,

Ro = Sensor resistance in fresh air.

Rs = Sensor resistance in displayed gases

Ro clean air factor = 10 (provided in the datasheet of the sensor)

pcurve = 3 values for a specific gas obtained from the curve provided in the sensor datasheet

The sensor is calibrated by dividing the sensor resistance by RO clean air factor. To find the gas concentration, first the gas percentage has to be calculated.

$$gas\ percentage = \left(\frac{\log(RsRoRatio) - pcurve1}{pcurve2} + pcurve0 \right)^{10}$$

Then the gas percentage is divided by Ro of that sensor to find the concentration of a specific gas,

$$gas\ concentration = \frac{gas\ percentage}{Ro}$$

After that, AQI level need to be measured according to the gas concentration. For CO, the following is the range for AQI index,

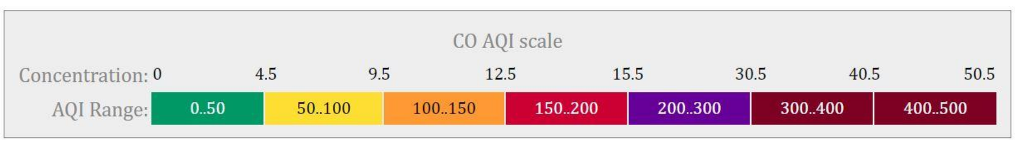

Figure 3.8: CO AQI scale

CO	AQI	Category	CO	AQI	Category
1	11	Good	12	143	Unhealthy
2	23	Good	13	159	Unhealthy
3	34	Good	14	176	Unhealthy
4	45	Good	15	193	Unhealthy
5	56	Moderate	16	204	Very
6	66	Moderate	17	211	Very

7	76	Moderate	18	218	Very
8	86	Moderate	19	224	Very
9	96	Moderate	...	...	Very
10	109	Unhealthy	31	306	Hazardou
11	126	Unhealthy	... 50	496	Hazardou

Table 1: AQI Scale for continues concentration of CO

As an example, if we get CO concentration 4, it can be said that AQI score is 45 the category is good.

3.6. Sending to cloud platform

We selected 6 data to be sent over the cloud to show. The server takes 1 input from Arduino in every 15 second. So, inside the code we set 6 variables, who's value to be uploaded to 6 different fields of the cloud channel.

Figure 3.9: Output of the device in cloud platform (mobile view)

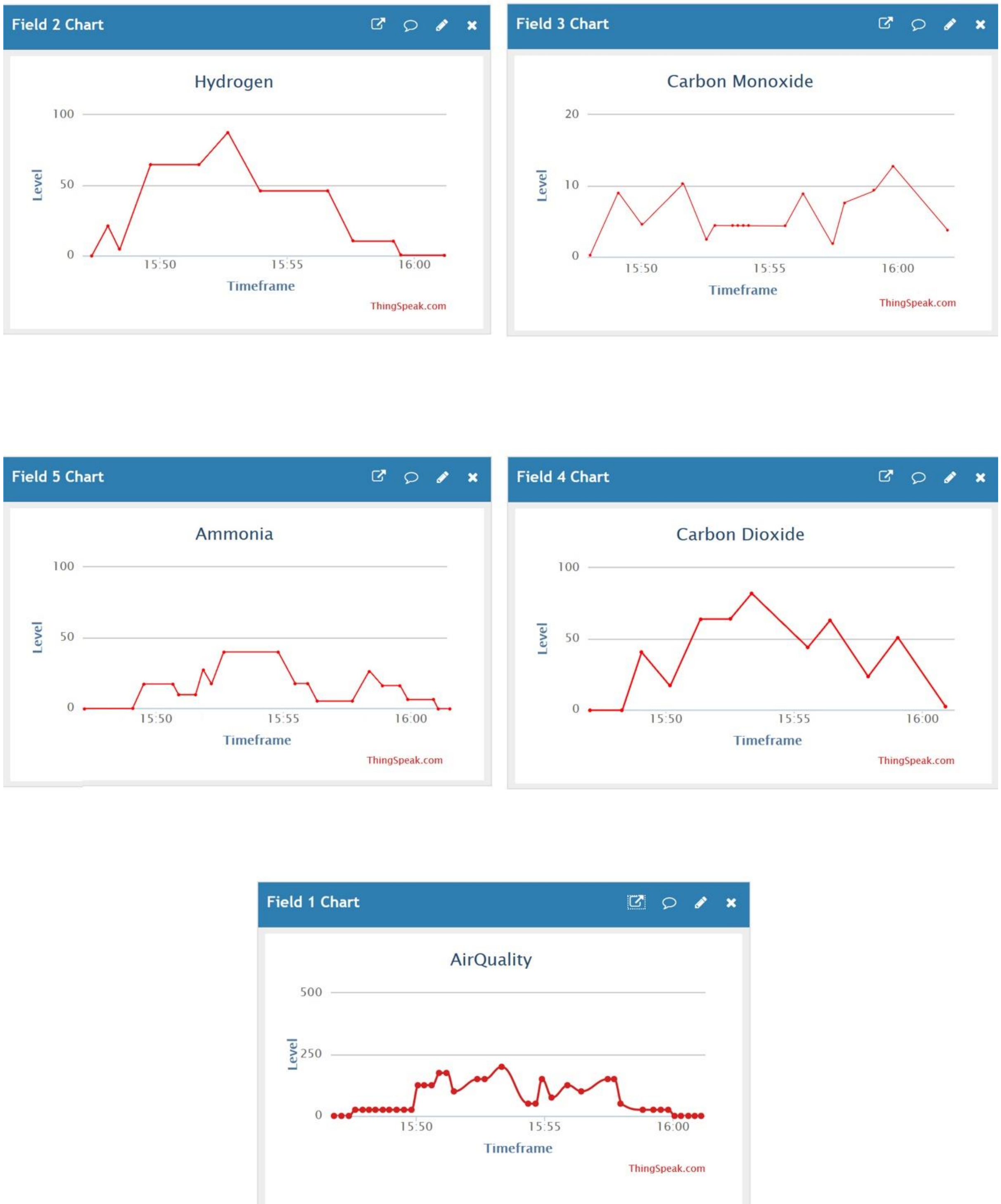

Figure 3.10: Output of the device in cloud platform (computer view)

3.7. Conclusion

In this section we discussed about the devices we used to develop our system. The circuit diagram of the whole system was shown and also the platform used for programming work. The formula that were used in the program to detect gas concentration was mentioned and described briefly

Chapter 4: Experiment and result

4.1 Introduction:

In this chapter, we have shown the findings of our thesis work. We have taken our device to different situation to see how much data do we get from our device.

4.2 Device Output in different environment:

The device was tested in polluted environment if it can detect gases and give decision on AQI value

Following are some data which were taken when the device was exposed to different object burning source:

H2 (ppm)	CO (ppm)	CO2 (ppm)	NH4 (ppm)	Temperature (Celsius)	AQI
42	1	284	22	31	Good
42	0	291	22	31	Good
45	1	295	24	32	Good

49	1	302	26	32	Good
56	2	315	25	32	Good
62	3	329	27	31	Good
71	5	340	28	31	Moderate
74	8	364	28	32	Moderate
77	10	389	28	32	Unhealthy for sensitive people
78	15	460	30	34	Unhealthy for sensitive people
75	12	486	29	34	Unhealthy for sensitive people
76	9	478	30	33	Moderate
73	7	461	31	34	Moderate
71	6	412	29	33	Moderate
68	4	348	28	33	Good
65	3	316	27	32	Good
62	1	292	25	32	Good
61	2	287	26	32	Good
55	1	277	25	32	Good

Table 4.1: Sample data outputs from our device

4.3 Building Dataset:

All the data taken by the Arduino from the gas sensors are exported automatically in a particular format to an Excel Sheet which will be used later on to analyze. With big amount of data and years of data, we can have the advantage to find more accurate results. Also we can predict the air quality for future days.

4.4 Conclusion

From the situation where our device was exposed, it gave back some data as outputs. We took to data to show in a tabled format and mentioned the importance of building a dataset for future analysis.

Chapter 5: Analysis with related dataset

5.1 Introduction:

In this chapter, we'll do some analysis with old dataset. We will discuss about it and the parameters and types of data it has. And we will also try to measure accuracy of the dataset so that with future data retrieved with our device, how we can predict town pollution.

5.2 Dataset information:

The dataset was obtained from the website of US Embassy of Bangladesh situated in Dhaka city [11]. The dataset contains concentration of PM2.5 and it's corresponding AQI score. Data was taken in every hour of a days, every day of months, and every month of years. It has AQI data from almost 20016 to 2018.

5.3 Analysis:

5.3.1 Environment Setup:

For our analysis we used R Studio. We installed several libraries required for the analysis. We tried to find the accuracy of the dataset by using Naïve Bias algorithm.

5.3.2 Performance metrics for classification:

In this section, we discussed about performance metrics we used for analysis.

Cross Validation:

In cross-validation, we decide on a fixed number of folds, or partitions, of the data. If we use n. Then the data is split into approximately n equal partitions; each in turn is used for testing and the remainder is used for training. Repeat the procedure n times so that in the end, every instance has been used exactly once for testing. This is called n-fold cross-validation [14]

Accuracy:

Accuracy is measured by dividing the total number of correctly classified instances by total number of instances.

Recall:

Recall (also known as sensitivity) is the fraction of relevant instances that have been retrieved over the total amount of relevant instances.

TP Rate:

$$TP\ rate = 100 \times \frac{TP}{TP + FN}$$

Where,

TP Rate = True Positive rate

TP = True Positive

FN = False Negative

FP Rate:

$$TP\ rate = 100 \times \frac{TFP}{FP + FN}$$

FP Rate = False Positive rate

FP = False Positive

TN = True Negative

F-Measure:

$$\text{F} - \text{Measure} = \frac{2 \times recall \times precision}{recall + precision}$$

5.3.2.1 Naïve Bayes Algorithm:

Naive Bayes classifiers are a collection of classification algorithms based on Bayes' Theorem. It is not a single algorithm but a family of algorithms where all of them share a common principle, i.e. every pair of features being classified is independent of each other [19]. The Naive Bayes Classifier technique is based on the so-called Bayesian theorem and is particularly suited when the dimensionality of the inputs is high. Despite its simplicity, Naive Bayes can often outperform more sophisticated classification methods.

Classification result for class: “AQI Category” with 10-fold cross validation:

Summary	Results
Correctly Classified Instances	97%
Incorrectly Classified Instances	2.8%
Kappa Statistics	0.9634
Mean Absolute Error	0.0164
Root Mean Squared Error	0.0819
Relative Absolute Error	7.5346 %
Root Relative Squared Error	24.8014 %
Total Number Of Instances	21094

Table 5.1: Classification result for class: “AQI Category” with 10-fold cross validation (1)

Evaluation Measure	10-Fold Cross Validation
Accuracy	97%
TP Rate	97%
FP Rate	0.005 %
Precision	0.974 %
Recall	0.972 %
F-Measure	0.972 %

Table 5.2: Classification result for class: “AQI Category” with 10-fold cross validation (2)

5.4 Results:

After the analysis we found this dataset has a high accuracy and with this dataset we can predict future outputs.

5.5 Conclusion

In this section we tried to apply Naïve Bias Classifier to measure the accuracy of the dataset we obtained from US consulate website. After using the classifier, we found 97% accuracy. So, it means by using pollution dataset we can predict future pollution based of different situations.

Chapter 6: Conclusion and Future Work

6.1 Introduction

We tried our best to give a model of a city where air pollution is monitored in a controlled way using IoT technology. However, there a few limitations we couldn't overcome yet. So, there are some plans to extend our work further in the future.

6.2 Future work

In our thesis work the model that we described and the device that we have built lacks some features as there were some sensors unavailable and for future work, we can propose a better device with better area coverage and set up multiple stations in the city with a central station for each city. By doing this in each city throughout the country we will be able to get which city or district is most polluted in Bangladesh and for which toxic gas the areas are affected the most and during what time the areas get polluted the most.

In our work we did not make a device that can cover a whole area because of the resources and budget that we had were not enough. And we could not work with two sensors that were needed to detect SO2 and O3. In Future we will try to include these sensors along with radiation detection so that we can give better results.

6.2.1 Govt. data

In Bangladesh, there is a project for measuring AQI which we discussed in section 2.2.1.3. The data gathered by that system is not available for public use. In future we plan to collaborated with that government project to enrich both the systems.

6.2.2 Disease analysis

It is a fact that because of air pollution, several respiratory diseases occur. So, it has a direct correlation with the number of people appearing to doctors and hospitals for those diseases. In future we plan to try and retrieve disease data from hospitals to establish the logical relation with air pollution and different kinds of diseases. With big number of data, it is possible to predict the number of people affected by which type of pollutions and the responsible gases.

6.3 Conclusion:

This work demonstrates the model that will help the country in the long run to control Air pollution more efficiently. When each station in a city delivers data to the base station of that city and finally to the base station of that district it will cover that whole district. And by doing the same for the whole

64 districts and finally sending the data to the county's base station and analyzing it, we can determine which area of which district is the most polluted and similarly which district is more than which one and what gases are responsible for the pollution and then we can take necessary steps to reduce the pollution and take other steps for further preventions

Appendix A: List of Acronyms

AQI:	Air Quality Index.
EPA:	Environmental Protection Agency
CO:	Carbon Monoxide.
PM2.5:	Particulate Matter 2.5
PM10:	Particulate Matter 10
SO2:	Sulfur Di Oxide
NO2:	Nitrogen Di Oxide
O3:	Ground level Ozone
H2:	Hydrogen
LPG:	Liquefied petroleum gas
CH4:	Methane
IoT:	Internet of Things
AQMP:	Air Quality Management Project
LPWA:	Low power wide area
CAMS:	Continuous Air Monitoring Station
TP:	True Positive
TN:	True Negative
FP:	False Positive
FN:	False Negative

Appendix B: Dataset for classification

*Only a few of 21094 data were presented

Site	Parameter	Date	Year	Month	Day	Hour	Now cast Conc.	AQI	AQI Category	Raw Conc.	Conc. Unit	Duration	QC Name
Dhaka	PM2.5 - Principal	7/5/2018 5:00	2018	5	7	5	21.7	71	Moderate	3	UG/M3	1 Hr	Valid
Dhaka	PM2.5 - Principal	7/5/2018 6:00	2018	5	7	6	13.3	54	Moderate	5	UG/M3	1 Hr	Valid
Dhaka	PM2.5 - Principal	7/5/2018 7:00	2018	5	7	7	24.1	76	Moderate	35	UG/M3	1 Hr	Valid
Dhaka	PM2.5 - Principal	7/5/2018 8:00	2018	5	7	8	26	80	Moderate	28	UG/M3	1 Hr	Valid
Dhaka	PM2.5 - Principal	7/5/2018 9:00	2018	5	7	9	37	105	Unhealthy for Sensitive Groups	48	UG/M3	1 Hr	Valid
Dhaka	PM2.5 - Principal	7/5/2018 10:00	2018	5	7	10	44	122	Unhealthy for Sensitive Groups	51	UG/M3	1 Hr	Valid
Dhaka	PM2.5 - Principal	7/5/2018 11:00	2018	5	7	11	41.5	116	Unhealthy for Sensitive Groups	39	UG/M3	1 Hr	Valid
Dhaka	PM2.5 - Principal	7/5/2018 12:00	2018	5	7	12	39.2	110	Unhealthy for Sensitive Groups	37	UG/M3	1 Hr	Valid
Dhaka	PM2.5 - Principal	7/5/2018 13:00	2018	5	7	13	31.1	91	Moderate	23	UG/M3	1 Hr	Valid
Dhaka	PM2.5 - Principal	7/5/2018 14:00	2018	5	7	14	40.5	113	Unhealthy for Sensitive Groups	50	UG/M3	1 Hr	Valid
Dhaka	PM2.5 - Principal	7/5/2018 15:00	2018	5	7	15	47.7	131	Unhealthy for Sensitive Groups	55	UG/M3	1 Hr	Valid
Dhaka	PM2.5 - Principal	7/5/2018 16:00	2018	5	7	16	45.3	125	Unhealthy for Sensitive Groups	43	UG/M3	1 Hr	Valid
Dhaka	PM2.5 - Principal	7/5/2018 17:00	2018	5	7	17	45.7	126	Unhealthy for Sensitive Groups	46	UG/M3	1 Hr	Valid
Dhaka	PM2.5 - Principal	7/5/2018 18:00	2018	5	7	18	38.3	108	Unhealthy for Sensitive Groups	31	UG/M3	1 Hr	Valid
Dhaka	PM2.5 - Principal	7/5/2018 19:00	2018	5	7	19	32.1	93	Moderate	26	UG/M3	1 Hr	Valid
Dhaka	PM2.5 - Principal	7/5/2018 20:00	2018	5	7	20	30	89	Moderate	28	UG/M3	1 Hr	Valid
Dhaka	PM2.5 - Principal	7/5/2018 21:00	2018	5	7	21	26	80	Moderate	22	UG/M3	1 Hr	Valid
Dhaka	PM2.5 - Principal	7/5/2018 22:00	2018	5	7	22	26.5	81	Moderate	27	UG/M3	1 Hr	Valid
Dhaka	PM2.5 - Principal	7/5/2018 23:00	2018	5	7	23	37.2	105	Unhealthy for Sensitive Groups	48	UG/M3	1 Hr	Valid
Dhaka	PM2.5 - Principal	8/5/2018 0:00	2018	5	8	0	42.6	118	Unhealthy for Sensitive Groups	48	UG/M3	1 Hr	Valid
Dhaka	PM2.5 - Principal	8/5/2018 1:00	2018	5	8	1	35.8	102	Unhealthy for Sensitive Groups	29	UG/M3	1 Hr	Valid
Dhaka	PM2.5 - Principal	8/5/2018 2:00	2018	5	8	2	29.4	87	Moderate	23	UG/M3	1 Hr	Valid

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