AIR QUALITY MONITORING USING IOT

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APPROVAL

This Project titled "**Air Quality Monitoring Using IoT**", submitted by Md Ibrahim, Md Navid Hasan, Tapati Sarker and ABM Nasim to the Department of Computer Science and Engineering, Daffodil International University, has been accepted as satisfactory for the partial fulfillment of the requirements for the degree of B.Sc. in Computer Science and Engineering and approved as to its style and contents. The presentation has been held on Thursday, October 8th, 2020.

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We hereby declare that; this project has been done by us under the supervision of **Dr. Syed Akhter Hossain, Professor and Head, Department of CSE,** Daffodil International University. We also declare that neither this project nor any part of this project has been submitted elsewhere for award of any degree or diploma.

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ABSTRACT

Air is one of the most essential tools of every human life, but for many years air pollution is a part of the world. By breathing pollutant air people are having many short- and long-term diseases, sometimes it causes immediate death. Since, people are spending most of their time in indoor area, indoor air pollution harms most to the human body and mind also. Our proposed system is indoor air quality monitoring using IoT. For experimental design we are proposing three nodes with different sensors, the system will measure the contaminant of air in real time by using low cost sensors, and measuring pollutants are Carbon Dioxide (MQ135), Carbon Monoxide (MQ7), Volatile Organic Compound (Grove-HCHO), Particulate Matter (PPD42NS, GP2Y1010AU0F), Temperature and Relative Humidity (DHT22). ESP-32 is used as development board. Every node will send contaminant measurement to a web server, where mobile and desktop user can read, and analyze the data.

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CHAPTER 1

Introduction

First industrial revolution period was started around 1760 to sometime in 1820 to 1840, which revolutionized manufacturing process in USA and Europe. This period gives a significant development to Textile Manufacture, Iron Industry, Steam power, Machine tools, Chemicals, Cement production, Gas lighting, Agriculture, Paper Machine, Mining and Transportation including Waterways, Roads and Railways. Growth of Industries leads to new work opportunities, people were moved to urban areas from rural area; where only 3% of the world's population by the year of 1800 used to live in urban area, currently over 56% of the world population are living in urban.

The Graph of Urban population growth from 1950 to 2050:

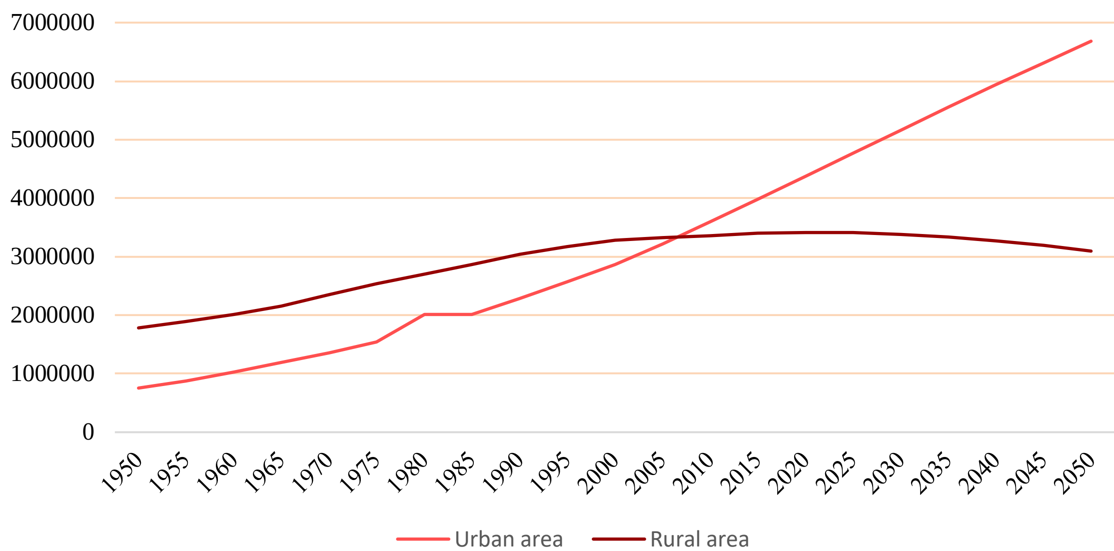

Figure 1.1: Effect of urbanizations (Increase of urban population and decrease of rural population) [1]

In the Figure 1.1, database of the United Nations Urbanizations Prospect shows that by the year of 1950, nearly 751 million people were lived in urban which is 26.6% of world population, in 2020 the number is over 4,378 million (56.2% of World population) and by the year of 2050, the number can reach to 6,680 million (68.4% of World Population). Bangladesh is one of the highly populated countries in the world, the urbanization is also largely impacted in the country which resulted 1.6 million people in 1950 (only 4.3% of the country's overall population) to over 64.81 million in 2020 (38.2% of total population) and the number could reach to nearly 118 million (58.4% of total population) by the year of 2050.

Coal was used as fuel in every development project in all over the world, it was one of the first step to disastrous Environment Pollution which is the main source of Carbon Dioxide, Particulate Matter expose. With development more and more people are hospitalized for breathing problem, most people didn't realize than how destroying this development could be, of course industrialization helped mankind to improving the way of living which comes with bigger destruction to every livelihood of the planet. The emission of carbon is not good for urban air and this idea leads to many movements throughout the history to reduce coal burning. But still tons of carbon are adding to the environment. For over 800 thousand years the CO_2 level was under 300 ppm in annually mean, figure 1.2 shows carbon dioxide data concentration from 1550 to 2018, In 1913 when CO_2 level exceeds 300ppm and having 301.3ppm in annually mean, and after 100 years CO_2 level reached to 400ppm and the year was 2015 (400.83 ppm). Obviously, industrialization is the reason for the instantaneously rise of CO_2 concentration, the dangerously rise of the Global Temperature and the over 4 trillion of ice melting in the Antarctica since 1950.

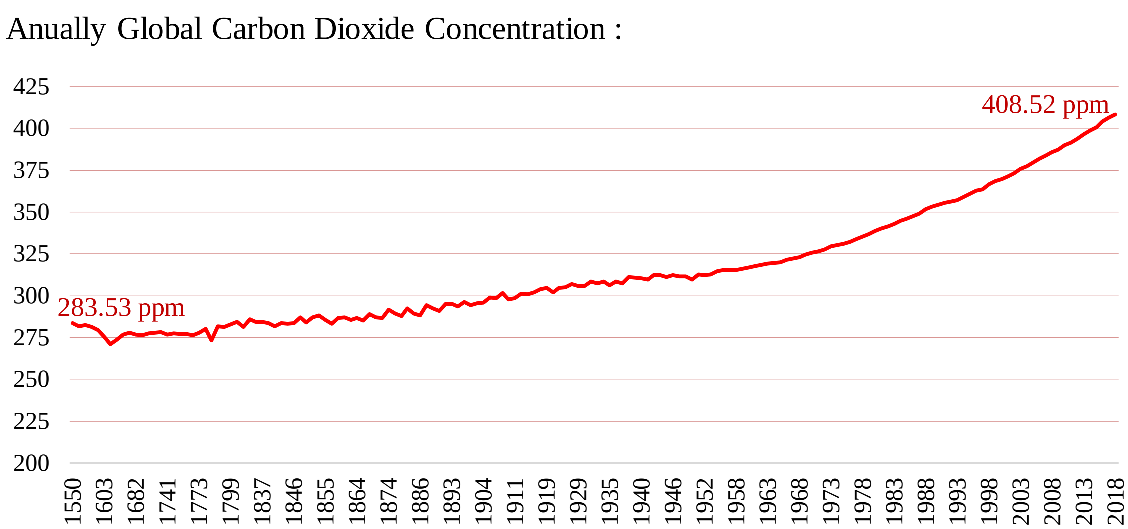

Figure 1.2: Global CO2 concentration from 1550 to 2018 according to ourworldindata.com [2]

Carbon Dioxide emissions in Bangladesh:

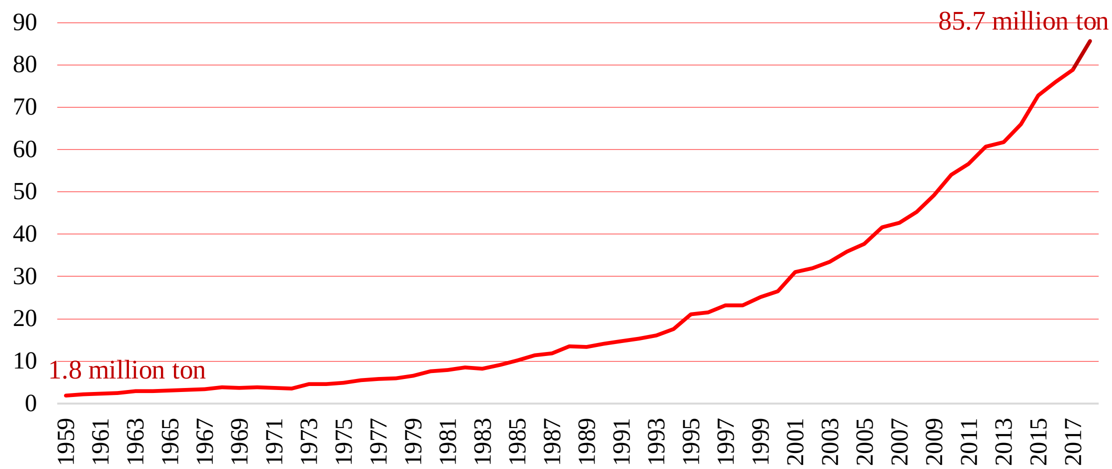

Figure 1.3: Carbon Dioxide concentration of the Bangladesh according to ourworldindata.com [2]

Figure 1.3 presents carbon dioxide emission data from 1956 to 2017, where it was 1.8 million to in 1959 but within 50 years in 2017 the emission level exceeds over 85 million ton. From ourworldindata.com, in the year of 2017 Bangladesh shares 0.22% of global carbon dioxide emission. But by the year of 1959 the country shared only 0.02% of global CO_2 emissions.

Like every industrialized city toxic contaminant Particulate Matters (PM-10 and PM-2.5) are also exist in Dhaka city, which are beyond permissible level for human body. PM2.5 means the particle is 2.5 micrometer in size which is over 30 times smaller than human hair. PM2.5 known as number one representative to measure of air pollution in a area. PM2.5 refers to particulate matter (ambient airborne particles) which measure up to 2.5 microns in size, and has a range of chemical makeups and sources. PM2.5 is widely regarded as the pollutant with the most health impact of all commonly measured air pollutants. Due to its small size, PM2.5 is able to penetrate deep into the human respiratory system and from there to the entire body through, causing a wide range of short- and long-term health effects like lung cancer, allergic effects, asthma, increasing respiratory problems which can lead to premature death.

Particulate matter is also the pollutant group which affects the most people globally. It can come from a range of natural as well as man-made sources. Common sources of PM include combustion, as well as through other pollutants reacting in the atmosphere. Transportation, industrialization, consumer products, natural sources like dust storm, pollen, bush fires etc., but in Bangladesh, industrialization and transportation are considered to be main sources of particle emissions where burning fuel (like: diesel) are widely used. Coal burning will not be 0 in so soon “The Perspective Plan for Bangladesh 2010-2021” shows that coal burning is going to rise over 53% in power plants. In table 1.1 we see in 2010, 88% of national energy source was gas, where coal was only 3.7%. But by the year of 2021 Bangladesh planned to increase the use of coal, which could reach 53% as national energy source.

Table 1.1: Energy sources of The Perspective Plan 2010 [3]:

Sources	Periods		
	2010	2021	2030
Gas	88%	30%	28%
Coal	3.7%	53%	38%
Oil	6%	3%	5%
Hydro	2.7%	1%	4%
Nuclear	0%	10%	19%
Renewable	0%	3%	6%

As the coal use of the country is rising, the country is going to suffer in a larger environmental crisis. It is going be a sleeping volcano, which can explode any time. Currently the number of annual PM2.5 emission is over 100µg/m3, where the number should not be exceeds over 8µg/m3. According to ourworldindata.com in figure 1.4, Bangladesh had nearly 67µg/m3 PM2.5 emissions at the end of 1990, 25 years later the number exceeds 100 marks and having over 101µg/m3 at the end of 2016. The number is still growing no one knows where it is going to be end, ourworldindata.com did not updated the number after 2016.

PM2.5 Concentration of Bangladesh:

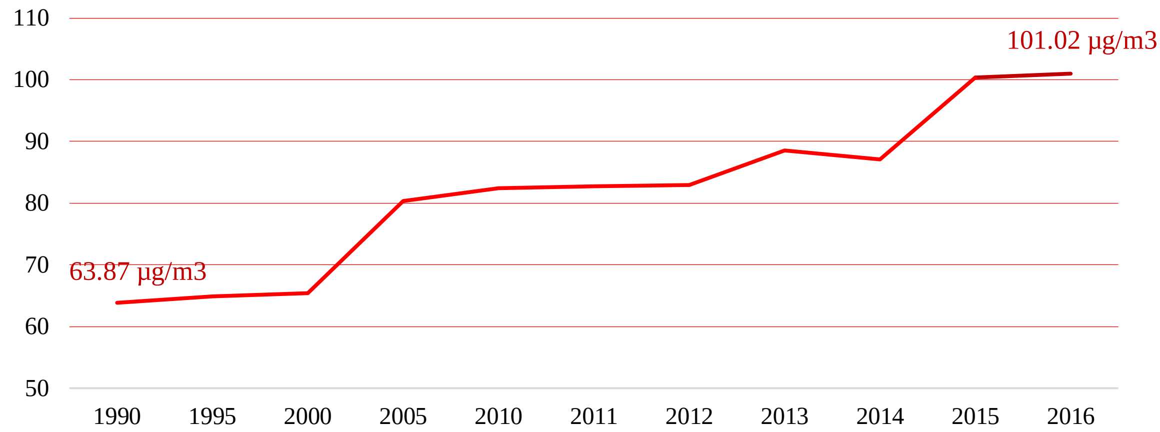

Figure 1.4: Rise of PM2.5 from 1990 in Bangladesh from 1990 according to ourworldindata.com [4]

According to ourworldindata.com Dhaka city, the capital of Bangladesh has nearly 20 million people which put the city one of the most densely populated urban area. The city is also one of the dirtiest cities in the world. IQAir shows city ranking, based on AQI from major cities of all over the world. In last few years Dhaka city was the number one ranked in most polluted city of the world. Fossil fuel burning is increasing day by day, with the rise of unpredicted behavior environment particulate matter emissions are also increasing. Before the Great Smog of London, which is also known as the Great Smog of 1952 developed countries did not have proper attention of increasing particulate matter. The London smog has killed over 1200 people and hundreds of thousands are injured. The smog was led to revolutionary changes in rules and regulations of government activities to reduce pollution, rise of public awareness about the healthy environment and public health and including the Clean Air Act 1956. In 1948 another gray smog in Donora, Pennsylvania, USA has affected over 14000 lives within 5 days which is led to study and research air pollution in USA. The Environmental Protection Agency was formed in USA at 1970, the study of 1950's and 1960's in multiple cities of USA helped to make Clean Air Act (CAA) - 1967 which is responsible for regulating air pollutant sources. The EPA calculate five major air pollutants (Carbon Monoxides, Ground Level Ozone, Particulate Matter, Sulfur Dioxide and Nitrogen Dioxide) regulated by CAA; EPA developed Air Quality Index to measure those air pollutant concentrations.

Table 1.2: Table of the bellow will give the understanding of the Air Quality Index (AQI) [5]

Air Quality Index levels of health concern	Numeric value (ppm-parts per million)	Explanations
Good	0 to 50	Air Quality is considered satisfactory and air pollution poses little or no risk at all
Moderate	51 to 100	Air Quality is quite acceptable but some pollutants can be dangerous for sensitive group like children, older people and people with chronic diseases.
Unhealthy for sensitive group	101 to 150	General people may not experience any health risk while sensitive group can be affected
Unhealthy	151 to 200	Sensitive group will experience serious health effect while normal people may experience some health issues
Very Unhealthy	201 to 300	This level requires health alert, everyone can experience serious health issues
Hazardous	301 to 500	This is an emergency condition for everyone, entire population is in serious health risk.

(Table 1.2 presents colored view of the levels of Air Quality Index (AQI) with health concern, which is developed by USA based Environment Protection Agency (EPA). Values above 500 ppm are considered to beyond AQI levels.)

Not only particulate matters are existing in Dhaka, Toxic elements like Carbon Monoxide, Hydrocarbon, Nitrogen Oxide, Sulfur Dioxides are also available. Emissions from Diesel engine elements like smoke, carbon monoxide, un-burned carbon, nitrogen oxides and Sulfur dioxide are polluting our air.

We don't realize that we are extremely exposed to toxic air polluted area which are leading us to permanent health disease like cancer, respiratory problems etc. day by day.

Many studies from Italy, China, UK and USA shows that COVID-19 death is severe in Air polluted area. A little amount of air pollution can lead to more and more death of human life. In this chapter we will present our motivation for the development project, importance of low-cost air quality monitoring system, expected output and project management and finance.

1.2 Motivation

Air is the number one essential tool for every living being, good air helps us to be more productive as well as it gives longer life and it is total opposite of bad air, in other words polluted air are circulating around us and we are inhaling over tens of thousands liter air per day including in indoor and outdoor. Air pollution is release off certain particles, chemicals and gasses to the environment. Pollutants are produced from vehicle exhaust, industries, coal burning, CFC gasses, wildfires, smoking cigar, wood burning, urbanization and many more. These are responsible for damaging Environment as well as human health.

Every life needs to breath to live and we breathe air around 20,000 times per day, and in the air, we inhale billions of tiny particles, gasses. Most of this air are polluted which contains a large number of toxic contaminants. One of every Eight deaths are directly caused by polluted air, more than 7 million lives lost in the world and millions of lives suffers various types of disease caused by air pollution. The United Nations set 20 sustainable goals, which includes multiple goals to reduce the number of death and disease caused by air pollution by the year of 2030. Goals related to air pollution are Good Health and Well-Being, Affordable and clean energy, Sustainable cities and communities and Climate action [6].

Yet most people over the world don't care about environment of the world (what we are doing to our water, our air, our wildlife and may more!!!). It seems we are living in this world as "It is the last day of my life". Even we don't think about what we are going to give our child, our ancestors, next generation of the world. We don't have the right to destroy the future of upcoming living creatures.

We are creating tons of CO_2, we are destroying Ozone-Sphere, and we are putting enormous danger to our wild life for hundreds of years. This destroying phase is going on and on. Already millions of lives are in danger in Bangladesh for water pollution and Air Pollution. We are those people who didn't take lessons from Chernobyl, we know that how terrifying it is having a nuclear power plant.
Disease like COVID-19 is turned into a global pandemic where thousands of people are dying every day for more than 6 months. No one able to figure it out when the world is going to be released from this crisis. This type of global emergency is happening for first time in mankind history.

Bangladesh, one of the most densely-populated countries in the world and for a long time Air Pollution is one of the biggest problems of the country. Dhaka is the country's capital, which is one of most polluted cities in global indices. For couple of years Dhaka is one the most air polluted cities in the world and Dhaka was hit no. 1 as most polluted city multiple times. Currently the city is under lockdown for CORONA pandemic; many industries are closed for a long time which helps to improve the quality of air but it is not safe yet at all.

According to a study by USA based Health Effects Institute (HEI) and Institute for Health Metrics and Evaluation (IHME) at least 1,23,000 people died in Bangladesh in 2017 due to air pollution, and the death rate is increasing day by day. In previous October Dhaka was listed for the first time as number one toxic city in the world. In a report of World Bank shows that Bangladesh loses nearly 6.5 billion Dollar in every year and top 5 death reason of the country is air pollution. Air pollution is present both inside homes and outside and is responsible for the premature death of seven million people each year, including 6,00,000 children, according to the special rapporteur's UN environmental annual report. Every hour, 800 people are dying, many after years of suffering, from cancer, respiratory illnesses or heart disease directly caused by breathing polluted air.

Brick kilns and vehicles run on fuel with higher level of sulfur have been identified as the major sources of air pollution in the country. In a report by US-based Environmental Protection Index (EPI) on the environment performance by the government of 180 countries, Bangladesh ranked 179, having slipped down by 40 places from the year 2010 to 2018. The report was published in September of last year. According to the Department of Environment (DoE) and the World Bank, brick kilns makes up 56 percent of the country's air pollution. The government had enacted a law in 2018 to make these kilns environment friendly, but a recent report indicated that of the 7,772 brick kilns in the country, 2,123 have not converted to the required modern and environment-friendly technology.

1.3 Rationale of the Study

We are largely exposed to air pollution whether it is indoor air or outdoor air. Air pollution has two types, 1st one is Indoor Air pollution and another is Outdoor Air Pollution. Many of us don't give proper attention to our indoor air quality. But most of the time Indoor air is much more dangerous, than outdoor air, since we spent large amount of our time in indoor whether it is School, Office or home, comparing with outdoor pollutants indoor pollutants are stuck in indoor which can leads to immediate death and short illness like headache, dizziness, eye iteration, nose iteration, throat iteration and many more or long term diseases like lung cancer, asthma, COPD (Chronic Obstructive Pulmonary Disease), pneumonia etc. An article from usatoday.com presents, people spends 90% of their time in indoor and named the generation as indoor generation.

Most of the time indoor air pollution is caused by outdoor pollution, the pollutants are circulating in indoor environment without proper ventilation system the pollution can be deadly. Table 1.3 shows data according to the ourworldindata.com by top seven risk factors where we see air pollution caused second most deaths. The number of deaths is over 1,20,000 per year for many years. In 2017, more than 1,22,700 people had died because of air pollution, where over seventy thousand deaths were caused by indoor air pollution and over fifty-six thousand deaths caused by outdoor air pollution, although indoor air pollution deaths in 2008 was more than 77.5 thousand and over 46.7 thousand deaths were caused outdoor air pollution. The indoor air pollution deaths were lowered to 68.5 thousand in 2015 but the number is increasing.

Table 1.3: Number of deaths of top 7 risk factor in Bangladesh (2007 – 2017) [6]

Year	High blood pressure	Air pollution	High blood sugar	Smoking	Indoor air pollution	Diet low in fruits	Outdoor air pollution
2008	121526	121052	86555	77040	77501	62053	46779
2009	126137	120316	86783	77941	75554	63375	47999
2010	132133	121480	89312	79768	75384	65471	49374
2011	132004	118544	88016	78283	72657	64618	49079
2012	134151	116331	88144	77123	69827	64143	49647
2013	137837	115577	90778	78401	70060	64247	48707
2014	141942	118341	95866	82319	69154	65133	52552
2015	145362	118768	99289	83932	68539	65795	53664
2016	150984	119102	103375	86299	69705	67423	52899
2017	157570	122734	109116	90795	70345	69563	56067

Unhealthy indoor air quality is responsible for lots of short- and long-term health problem which can issue very low productivity, damaging mental health as well as physical wellbeing. Many indoor pollutants are more deadlier than outdoor pollutants, TVOCs (Total Volatile Organic Compounds), Carbon monoxide, asbestos are few of them. An Ideal Indoor air quality monitoring device can give us a good understanding of the air we breathing.

We need to monitor our Air Quality whether it is in dangerous level or not, if it is above of comfortable state, we have to take action to reduce the pollution. Traditional Air Quality monitor is expensive, setup and maintenance costly; where low-cost Sensors can give relief to this situation. It is easy to setup and easily maintainable, using IoT measurement data can be uploaded to cloud and can be monitored from anywhere. We need to conduct more study on pollution impact, why we need to track our air quality, how the pollution is leading to global warming, different types of health risks, reasons behind devastating air pollution and most harmful air pollutants around us to raise awareness.

Currently Six air quality monitoring stations are available in the Dhaka city, and their real time data uploaded to iqair.com, all six stations take outdoor pollution concentration. And the stations are not able to give the proper concentration of all over the city, because the station number is very low. In this situation we are not able to get exact air quality monitoring data changing over place to place and time to time. BUET, Dhaka University and Jahangirnagar University has multiple projects to monitor air pollution, study and analyze those monitored concentration to improve air quality of Bangladesh. We need to increase the number of stations and contribute the data for large scale study to develop a system to reduce air pollution.

1.4 Research Questions

As we are working with this project for a long period, lots of questions raises. Some of them we have noted bellow:

1. What are the reasons behind to choose this topic?
2. What people need to know about the air they are breathing?
3. What are the main air pollutants?
4. How air pollutants are affecting our daily life, our productivity, our health and mind?
5. Which pollutant hurts us most, and which pollutants we are going to detect?
6. What types of paper we have to study for the development project?
7. How researcher around the world are working to solve the problem?
8. Which sensors are widely used by them and what are the sensor type?
9. How we are going to detect toxic pollutants?
10. How to study data sheet of a sensor and why it is important?
11. How many nodes are required in our development project?
12. How many sensors will be used in each node?
13. How much cost required for each node?

14. What are the positions those nodes need to set to get proper data?
15. Which sensors are available in the local market?
16. Which sensors we are going to use?
17. What information are required to work with those sensors?
18. How we are going to collect detected data?
19. What is the appropriate time interval between data transmission?
20. How can we make the data easily accessible for mobile or desktop users?
21. How can we create a user interface which could help us to understand the dangerousness of air pollution?

1.5 Expected output

Our project will measure Particulate Matter, Volatile Organic Compound, Carbon Dioxide, Carbon Monoxide, Temperature and Relative Humidity of air in real time. At the end of our project we want to present three different air quality monitoring device and a website with real time air quality monitoring data, from three different sensor node.

CHAPTER 2
BACKGROUND

This chapter includes some preliminary information about our project and some information about related projects as well as a little comparison between different categories of sensors and some working challenges too.

2.1 Preliminaries

There are over thousands of air quality monitoring projects all over the world, thousands of researchers are working to monitor and reduce air pollutants. It is great for the field that it can help to raise awareness about air around us, care for the air we are breathing will ultimately help us to live longer, stay healthy, being much more productive at the end of the day making the world a better place for all of living beings.

In this development project we are working with three different nodes:

Node_1 will detect Carbon Dioxide, Carbon Monoxide, Particulate matter, Volatile organic compounds alongside with Temperature and Humidity.
Node_2 will detect Particulate matter, Carbon Dioxide, Carbon Monoxide with Temperature and Humidity.
Node_3 will detect Carbon Dioxide, Carbon Monoxide, Temperature and Humidity.

We have studied more than fifty conference / journal paper, over hundreds of websites about air pollution monitoring and reducing technique to select perfect sensors for our nodes.

2.2 Related Works

In table 2.1, we have enlisted twenty-four related research projects.

Table 2.1: Related Development projects

Contents	[7]	[8]	[9]	[10]	[11]	[12]	[13]	[14]	[15]	[16]	[17]	[18]
Network Protocol	WiFi	LoRaWAN				WSN	WiFi					
Transmission Module						NRF24L01	ESP8266	CC2650		ESP8266		
Display Device		OLED			LED	LCD12864						
VOC						MQ138						
CO	MQ9		MiCS-4514		MQ2						8552/8554 Q-Trak Plus	MQ7
CO_2	MQ135	T6713	CDM710	MQ2			MQ-135		MQ-135	K30 STA	8552/8554 Q-Trak Plus	MQ6
O_3												
NO_2			MiCS-4514								GAXT-D	
SO2											GAXT-S-DL	
Methane												MQ135
GAC												
Particulate Matter	DSM501A	SM-PWM-01C	PPD42	SM-PWM-01c		GP2Y1010AU0F				PMS3003		
Temp	DHT22	T9602	SHT21	DHT22					DHT11	T9602-3-D-1		DHT11
RH	DHT22	T9602	SHT21			DHT11			DHT11			DHT11
Motion										TB-XC4444		
Noise				LM386								
Pressure			BMP 180									
UV				SI1145								
Microcontroller	ATMEGA-328p	Arduino Uno	Arduino Mega 2560		Intel Edison Board	STC12C5A60S2	PIC16F877A	Raspberry Pi	ESP8266	Arduino Pro Mini	PIC 18F4550	Raspberry Pi

Contents	[19]	[20]	[21]	[22]	[23]	[24]	[25]	[26]	[27]	[28]	[29]	[30]
Network Protocol	WiFi	ZigBee	Bluetooth, WiFi	ZigBee	ZigBee		ZigBee	WiFi	WiFi	WSN, XBee		WSN, ZigBee
Transmission Module						TGS2602,MOCON		ESP8266	ESP8266			eZ430-RF2500
Display Device												
VOC	TGS822							MQ135		TGS2602		TGS2602
CO	TGS203			TGS2442				MQ7	MQ7	MQ7		TGS0425
CO_2		NDIR	TGS2442	TGS4161		S100	MG-811					T6613
O_3			MiCS2611							MQ131		MiCS2610
NO_2							MQ-135		MiCS2710		MiCS-2714	GSNT11
SO2							MQ-6	MQ2	MQ136		SO2-A4	SO2-AF
CH4	TGS842								MQ4			
GAC	TGS800				TGS 2600							TGS2600
Particulate Matter									DSM501			GP2Y1010AU0F
Temp	SMT160-30				LM32DZ					RTH03		DHT11
RH	HM1500				HIH-4000					RTH03		DHT11
GPS									REB-1315S4			
Microcontroller								Arduino	ATMEGA 328p	Atmega 328	Waspmote Gases Pro v3	MSP430f2274

2.3 Comparative analysis and Summary

Some categories of sensors are Electro-Chemical sensors, Metal-Oxide Sensors, Optical Particle Counters, Photo-Ionization Sensor, and Optical sensors. NO_2, SO_2, O_3, NO, CO sensors are basically Electro-Chemical Sensors which based on the chemical reactions between gasses in the air, and these types of sensors are highly sensitive to temperature and relative humidity. Metal-Oxide Sensor (MOS) is also known as semiconductor or resistive sensor. VOC sensors are usually Photo-Ionization Sensors which are less affected by temperature but humidity can affect. Optical-Particle Counters are mostly used for measuring Particulate matter, the sensor can able to detect as small as 1µg/m3.

There are many sensors given in table 2 which are not available in our local market. As we are measuring CO, CO_2, PM, VOC, Temperature and Relative Humidity, we choose to use MQ7 as CO Sensor, MQ135 as CO_2 Sensor, PPD42NS and GP2Y1010AU0F as Particulate matter sensor, Grove-HCHO as VOC Sensor, DHT22 as Temperature and Relative Humidity Sensor. We are using ESP32 as development board.

2.4 Challenges

We need to choose sensors with high accuracy level and low cost which should be available in our local market for future study. We have collected a lot of sensors for our development project but some of those are not available currently in our local market, one is grove-PPD42NS dust sensor and another one is grove-HCHO formaldehyde sensor. Every electronic component has a datasheet, before writing code for sensor every datasheet requires proper study to get desired pollutant data.

All sensors need DC power supply, it can be either 5 volts or 3.3 volts, managing proper supply for every sensor is quite a challenge. Sending measured data to cloud and view these data in a website is requires a hard work. An interactive user interface can help users in enormous ways to raise awareness about our air.

Two of the biggest challenges were collecting required money for the project and getting together to work on this project during the global pandemic. Thanks to Almighty that we were able to overcome those challenges and completed our project successfully.

CHAPTER 3
PROJECT DEVELOPMENT

As we are planning to develop four different contaminants of indoor air alongside with temperature and relative humidity, we needed gather in depth information's on those contaminants. This chapter we will present depth information of our proposed system and its implementation, starting with required data, instrumentation and data collection procedures to complete our project.

3.1 Research Subject and Instrumentation

At first, we have done study on which air contaminants are most severe for our environment and livelihood. We got to know many pollutants, where some contaminants affect most like Nitrogen Dioxide (NO_2), Sulfur Dioxide (SO_2), Ozone (O_3), Carbon Dioxide (CO_2), Carbon Monoxide (CO), Particulate Matter (PM), Volatile Organic Compounds (VOCs). In this project we are going to work on some indoor air contaminants which are CO_2, CO, PM>1µm, Formaldehyde (VOC), Temperature and Relative Humidity.

Carbon Monoxide (CO) is a gas and it is colorless, higher level of CO can cause immediate death or many long-term health issues. It can cause severe health problem for sensitive group of people like elderly people with heart disease. The main source of CO is fuel burning by industrialization and transportation system, according to EPA over 88% of CO emissions are comes from fuel related burning process, figure 3.1 shows the sources of Carbon Monoxides where 56% of CO comes from On-Road vehicles, 22% comes from Non-Road Vehicles and engines, 12%, 6% and 4% come from Miscellaneous, Fuel combustion and Industrial Process respectively. Sometimes CO can build up in indoor area where proper ventilation is not available. Sensors like MQ9, MiCS-4514, MQ2, TGS203, TGS2442, MQ7, and MQ135 (see also Table 2.1) can be used to detect CO measurements, but MQ7 is one of the highly sensitive sensors for detection of Carbon Monoxide.

Sources of Carbon Monoxide:

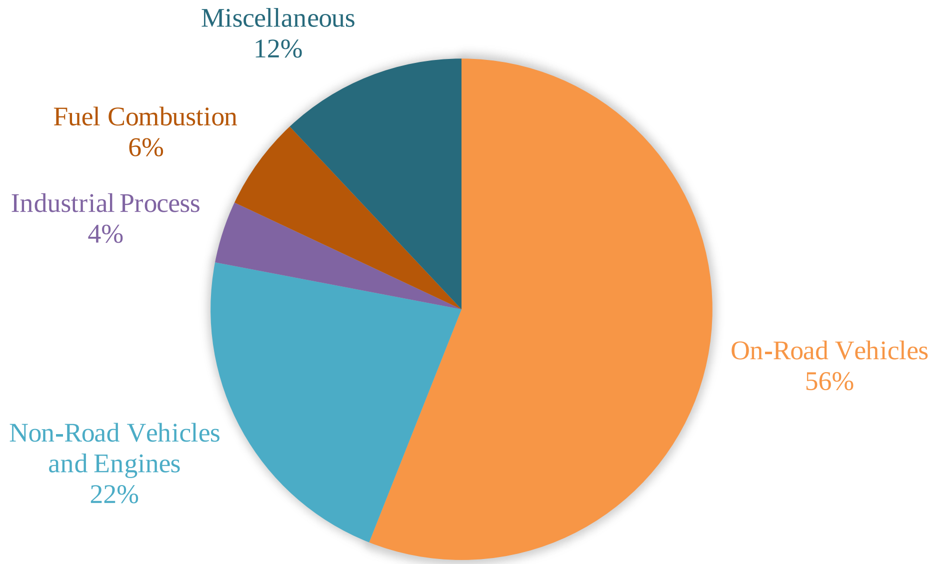

Figure 3.1: CO sources (from US-EPA) [7]

Carbon Dioxide (CO_2) is also a colorless gas air contaminant, which is the main driver of climate change and humans are responsible for most CO_2 emissions (Figure-1.2 and Figure-1.3 shows local and global CO_2 raising). It is also known as global disaster made by humans and every living being are facing thousands of health problem around the world. CO_2 emissions are not only dangerous for human health but also dangerous for total cycle of life. Wood burning, Cooking, Fuel combustion are main sources of CO_2 emissions, figure 3.2 shows carbon dioxide sources in percentage. Sensors like MQ135, T6713, CDM710, MQ2, K30STA, MQ6, TGS2442, TGS4161, S100, MG811, and T6613 (see also Table-2.1) can be used to detect CO_2, where MQ135 is one of the highly sensitive sensors for CO_2 detection.

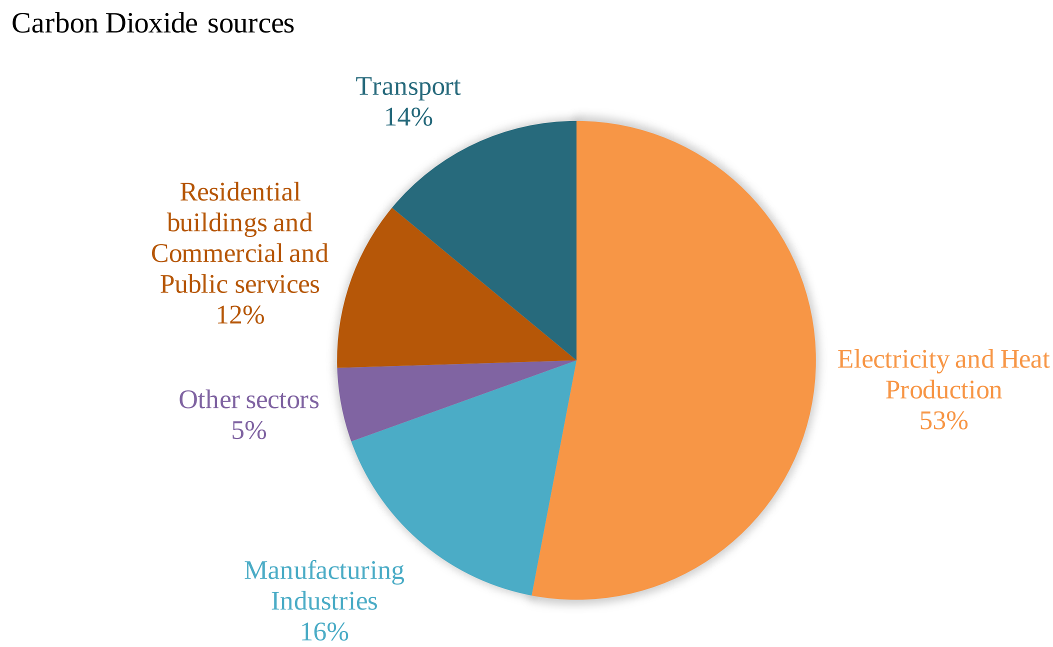

Figure 3.2: Carbon Dioxide emissions in Bangladesh at the end of year 2014 [8]

Particulate Matter is mixture of droplet, dust, smoke, dirt etc. which are so small that cannot be seen in naked eyes. It can be less than 1 micrometer, which get into human body through nose during breathing, mouth or eyes. The contaminant can reach the whole body by mixing in blood cell and cause many short- or long-term health problem for all kind of living beings. Currently air quality of a location is measured by the particulate matter level of that place. In figure 1.4; we can see the increment of PM contaminant over time in Bangladesh from 1990 to 2016. Particulate Matter has hundreds of sources since it is mixtures of multiple particles, Transportation, industrialization, Consumer products, Natural sources like dust storm, pollen, bush fires are some examples of many sources, figure 3.3 and figure 3.4 shows main sources of particulate matters (PM2.5, PM10) in percentage. Two types of particulate matter get the most attentions, which are PM2.5 (Particulate Matter 2.5 which is thirty times smaller than human hair) and another one is Particulate Matter 10, size of PM2.5 is 2.5 micrometer (μm) and size of PM10 is 10 micrometer (μm). Sensors like DSM501A, SMPWM-01C, PPD42, PPD42NS, GPY1010AUF, PMS3003, and DMS501 (see also Table-2.1) etc. can be used to detect PM contaminant in air. PPD42NS can detect minimum 1μm particle in air, this sensor gives output value in µg/m3, and it is one of the most used Particulate Matter Sensors with such a low cost. GPY1010AUF is also another most used particulate matter sensor.

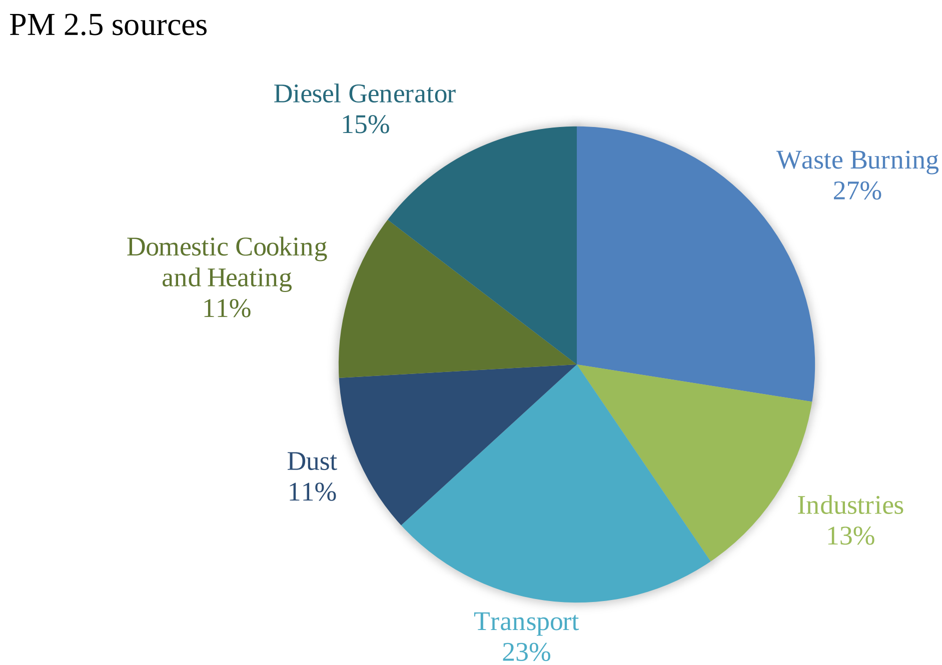

Figure 3.3: Particulate matter 2.5 emissions by sources [33]

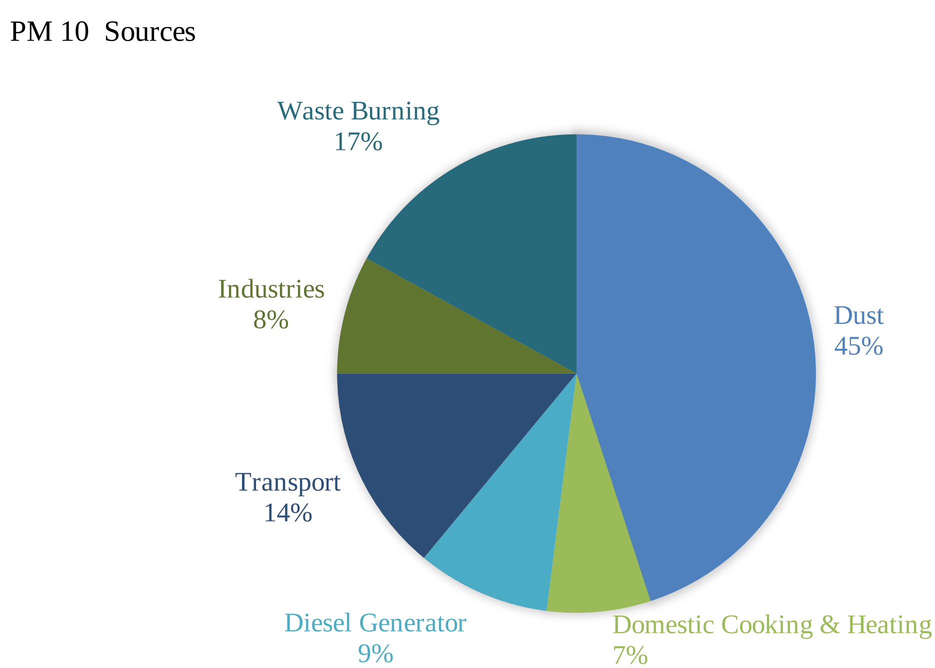

Figure 3.4: Particulate Matter 10 emissions by sources [33]

Volatile Organic Compounds are group of chemical compounds which are emitted in form of gases from different types of solid or liquid. There are over hundreds of VOC are available in environment; Formaldehyde, Propane, Benzene, Alcohol, Ethanol, Butane are some common VOC's. VOC's can raise many short- and long-term health effects like headaches, eye iteration etc. high level of VOC's can damage liver, kidney and nervous system. Main source of VOC's is household products like pesticide, paint, air fresheners, disinfectants and automotive products etc. figure 3.5 shows VOC sources. And the level of VOC is normally 2 to 5 times higher in indoor with respect to outdoor, sometimes it is 1000 times higher in indoor. Kitchen, basement, bathroom has higher level of VOC's in an apartment. Sensors like MQ138, TGS822, MQ135, and TGS2606 (see also Table-2.1) etc. can be used as VOC's detection sensor.

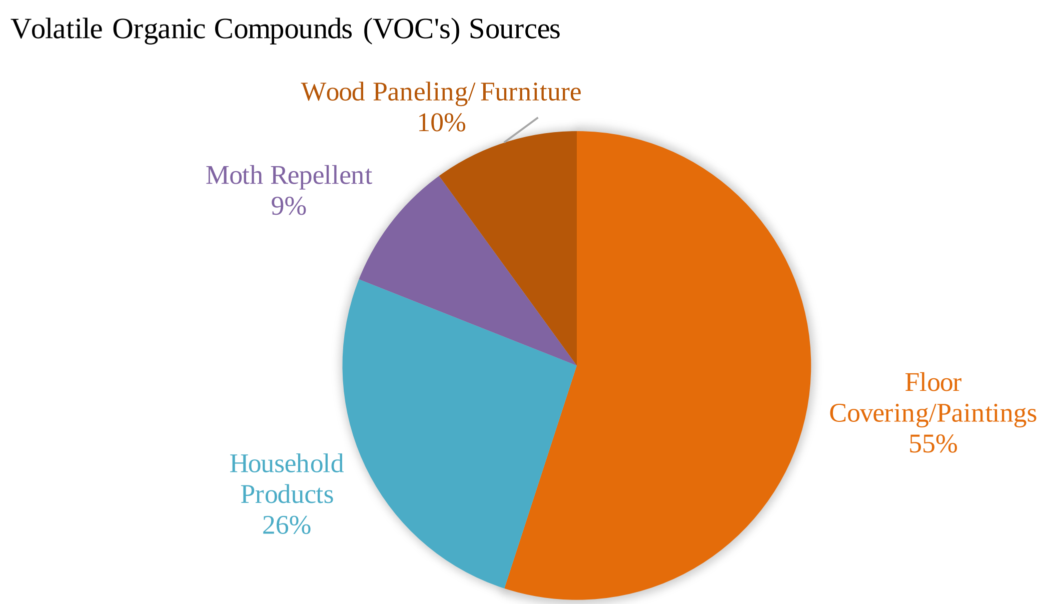

Figure 3.5: Sources of VOC's [34]

Most air contaminant are highly depended on temperature; global warming is a key sign of environment change. Very low and high level of humidity can create health problems.

3.2 Proposed System

Our proposed concept is making three different nodes (Node_1, Node_2, and Node_3) and a web server. All node can detect some common air pollutants like- carbon Dioxide and carbon monoxide with temperature and relative humidity. Node_ 1 will detect Particulate Matter and Formaldehydes (VOC) with the common pollutants. Node_2 will detect Particulate Matter with common pollutants. We are using an LCD display in Node_1, where CO, CO_2, VOC, PM, Temperature and Humidity will be presented in real time. We are using a RGB LED and Buzzer module in every node, whenever any pollutant emissions goes over human comfort level the LED will turn into Yellow color and the buzzer will beep two times per minute, whenever any pollutant level can make health problem the LED will turn into Red color and the buzzer will beep ten times per minute.

Simple Illustration of Proposed system

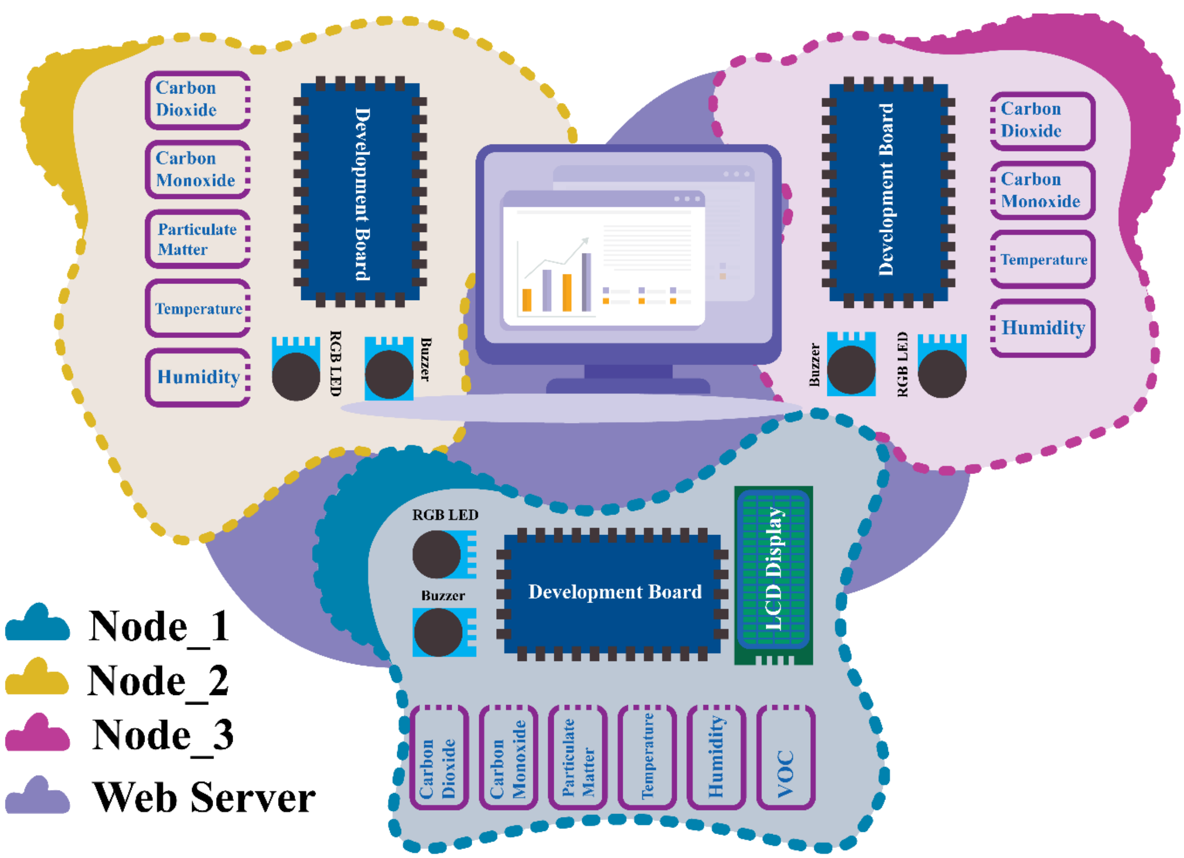

Figure 3.6: Proposed concept illustration

In this concept every node will send real time data to the server, both PC and mobile users can monitor the data and analyze them for further study. In figure 3.6 we present the illustrative idea of the proposed system.

3.3 System Components

We are going to use DHT22 as Temperature and Relative Humidity sensor, Grove-PPD42NS and Sharp- GP2Y1010AU0F as Dust sensor, MQ7 as Carbon Monoxide sensor, MQ135 as Carbon Dioxide Sensor, RGB LED for light signal, buzzer module for sound signal and ESP-32 as development board for all nodes. We choose to use ESP-32. Because, it is one of the best IoT Development Board available in the world. We are using ESP-WROOM-32 with 30 pins module. This development board also has 40 pins module which is not available in our local market. Although 30 pins module has more than enough feature to build our project. ESP-32 has built in Wi-Fi and Bluetooth module and Arduino IDE is used to write and upload code in ESP-32.

Table 3.1: Components for Node_1

SL	Name	Sensor	Qty	Operating Voltage	Output signal type
1	Temperature and Humidity	DHT22	1	3.3v	Digital
2	Particulate Matter	PPD42NS	1	5v	Digital
3	VOC	Grove HCHO	1	5v	Analog
4	Carbon Monoxide	MQ7	1	5v	Analog, Digital
5	Carbon Dioxide	MQ135	1	5v	Analog
6	Display (20x4 LCD)		1	5v	
7	ESP-32		1	3.3v	
8	RGB LED Module		1	5v	
9	Buzzer		1	3.3v/5v	
10	Power Supply Stick		1	7v-12v	
11	Jumper Wires		40+		
Total			50+		

Table 3.1 shows components for Node_1, sensors for each contaminant and their quantity, operating voltage and output signal types. We need jumper wire as required it can be more than 40, we have to gather enough jumper wires because we don't want to fall short during wiring.

Table 3.2: Components for Node_2

SL	Name	Sensor	Qty	Operating Voltage	Output signal type
1	Temperature and Humidity	DHT22	1	3.3v	Digital
2	Particulate Matter	GP2Y1010AU0F	1	5v	Digital
3	Carbon Monoxide	MQ7	1	5v	Digital, Analog
4	Carbon Dioxide	MQ135	1	5v	Analog
5	ESP-32		1	3.3v	
6	RGB LED Module		1	5v	
7	Buzzer		1	3.3v/5v	
8	Power Supply Stick		1	7v-12v	
9	Jumper Wires		40		
Total			48		

Table 3.2 shows components for developing Node_3, measuring sensors and their quantity, operating voltage, output signal types. We are not using VOC measuring sensor in Node_2 so Grove-HCHO not included and particulate matter changed to Sharp-GP2Y1010AU0F in table 3.2.

Table 3.3: Components for Node_3

SL	Name	Sensor	Qty	Operating Voltage	Output signal type
1	Temperature and Humidity	DHT22	1	3.3v	Digital
2	Carbon Monoxide	MQ7	1	5v	Analog, Digital
3	Carbon Dioxide	MQ135	1	5v	Analog
4	ESP-32		1	3.3v	
5	RGB LED Module		1	5v	
6	Buzzer		1	3.3v/5v	
7	Power Supply Stick		1	7v-12v	
8	Jumper Wires		30		
Total			37		

Table 3.3 shows components for Node_3, sensors and their quantity, operating voltage and Output signal types, since we are measuring CO and CO_2 with temperature and relative humidity so only three sensors are included in the table.

3.4 Wiring and Code

In our project, Node_1 has the most components, so we wanted to make our experiments on the Node_1. We have done couple of experiments on Arduino development board, these experiments helped us to write proper code for each sensor after datasheet study. We had couple of problems like power supply to sensors, since we were experimenting with multiple components Arduino board does not able give power to all of them so we needed an extra power supply board. VCC and GND pins of all component connected with a power supply stick module, which is also connected with an AC/DC adaptor, the adaptor can give 12-volt output. The power supply we have used can work with 7 to 12-volt DC power. All connections are given through different types of jumper wires. As we are using ESP32 as our main development board we had to make change in our codes. Figure 3.7 is the image with all connection between components. In table 3.4 we have enlisted the connection between components and development board with short notes.

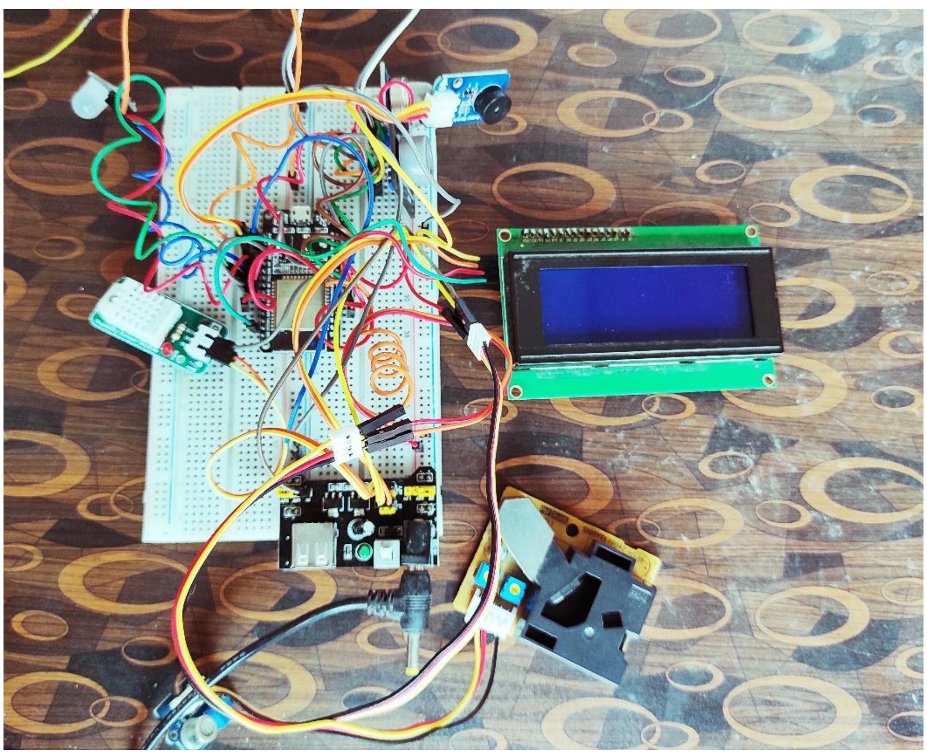

Figure 3.7: Wiring project demo

Table 3.4: pin connections with ESP-32

ESP32 Pin No	Components	Notes
GPIO 4	RGB LED	R pin of RGB LED connected with GPIO 4 pin
GPIO 5	DHT22	DHT22 sensor gives digital data and the sensor connected with GPIO 5 pin
GPIO 12	PPD42NS	PPD42NS also gives digital data and the sensor connected with GPIO 12 pin
GPIO 15	MQ7	MQ7 gives both digital and analog data, analog output pin connected with GPIO 15 pin
GPIO 16	RGB LED	B pin of RGB LED connected with GPIO 16 pin
GPIO 17	RGB LED	G pin of RGB LED connected with GPIO 17 pin
GPIO 18	Buzzer	SIG pin of buzzer module connected with GPIO 18 pin
GPIO 21	LCD	Serial Data (SDA) pin of LCD module connected with GPIO 21 pin
GPIO 22	LCD	Serial Clock (SCL) pin of LCD module connected with GPIO 22 pin
GPIO 32	MQ7	Digital output pin of MQ7 connected with GPIO 32 pin
GPIO 33	MQ135	Analog output pin of MQ135 connected with GPIO 33 pin
GPIO 34	HCHO	Signal pin of Grove-HCHO Connected with GPIO 34 pin

In code writing phase, we used Arduino IDE to write and upload code to ESP-32 development board. We have written nearly 170 lines of code for only Node_1 demo, and code explanation will increase the size of report. We had to make some changes in our code like pin number, analog input (Arduino can take analog input in between 0 to 1023, where ESP32 can take analog input in between 0 to 4095). Figure 3.8 is a picture of output after uploading code to ESP32.

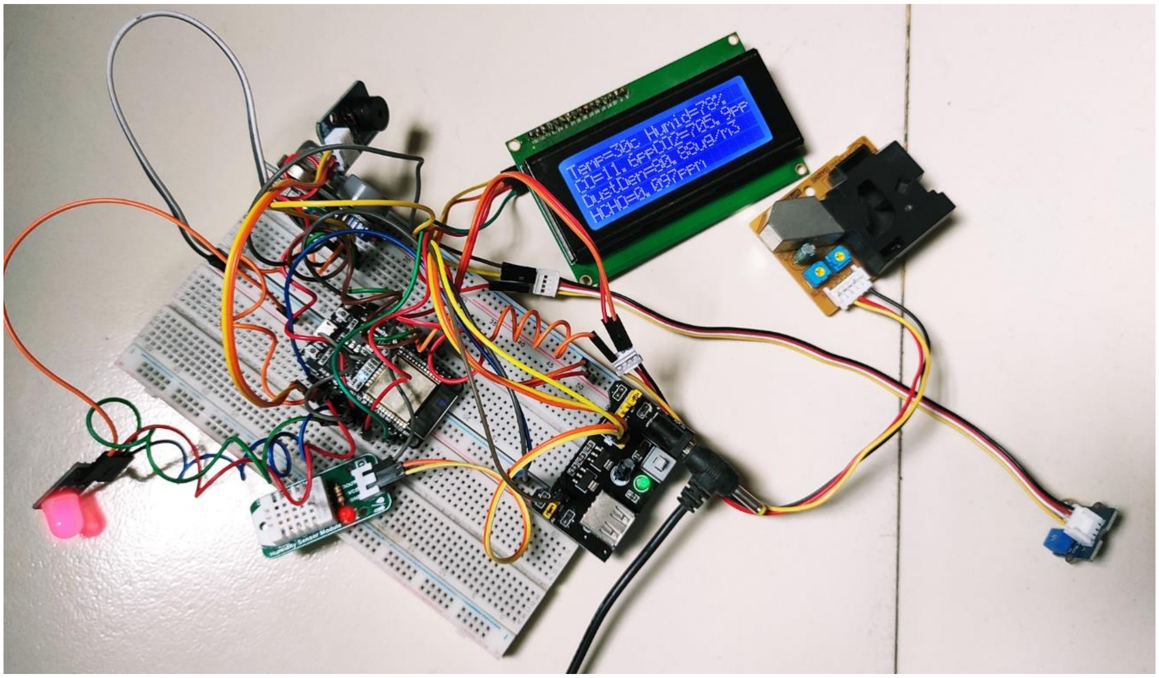

Figure 3.8: Output in LCD module after uploading code to ESP32 board

Our Node_1 demo was successfully implemented after many failures. When Node_1 succeed, our Node_2, and Node_3 are also implemented similarly as Node_1 but some components are reduced as we can see in Table 4 and Table 5.

3.5 Schematic and PCB Design

We have used Proteus 8 professional for schematic and PCB Design, there are many PCB designing software available. But we choose to work with Proteus because we have little experience on the environment and Proteus has the largest device library. Although devices of our components is not available in the device library of Proteus so we needed to design our own devices for schematic and PCB Design. We have designed an ESP32 Development board, MQ135, MQ7, Grove-HCHO, Buzzer, RGB LED, MQ7, and Grove-PPD42NS, and GP2Y1010AU0F for schematic design device. Figure 3.9 is a screen shot of devices we have designed and saved in Proteus library.

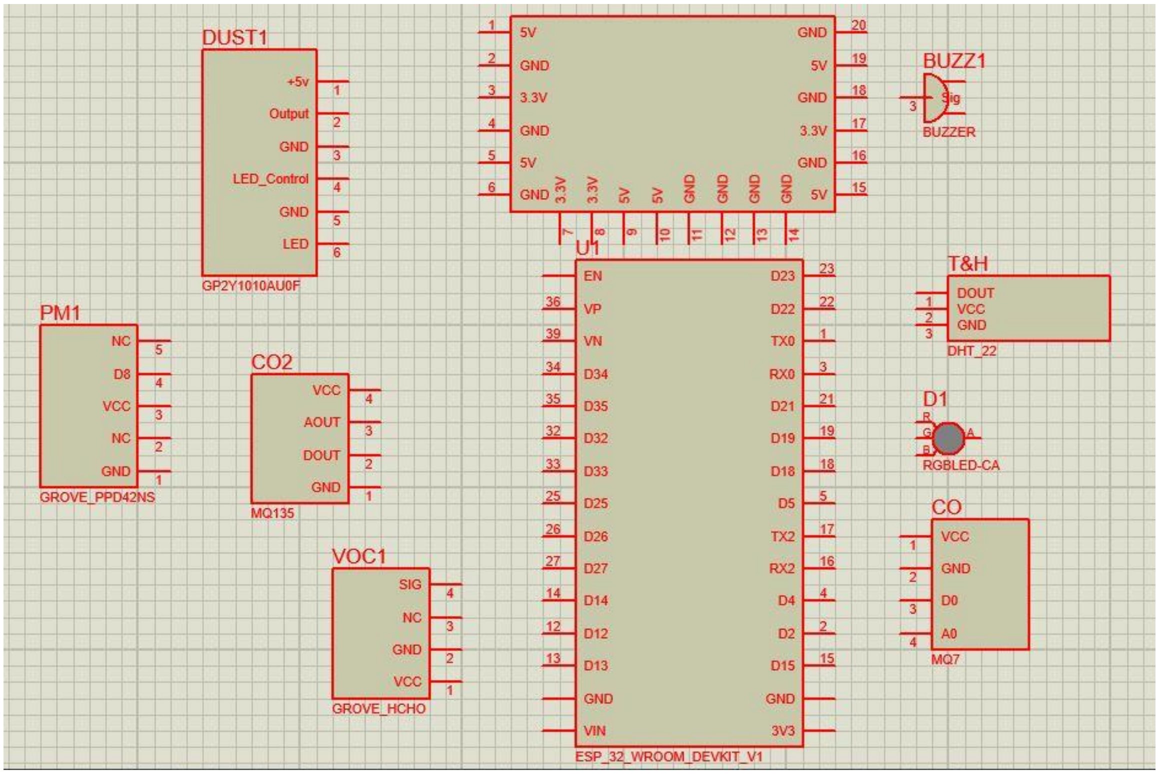

Figure 3.9: Device Design in Proteus 8

In figure 3.10, we have connected all devices by following Node_1 experiment, where Grove-PPD42NS was used as PM sensor. MQ135 as CO_2 sensor, MQ7 as CO sensor, Grove-HCHO as VOC sensor, DHT22 as Temperature and Relative Humidity Sensor, one power supply stick used to give power to all components, an LCD 20x4 display to show contaminant measurement, a Buzzer to beep whenever any contaminant is over comfort level and a RGB LED to indicate whether contaminant level is in comfort level or not.

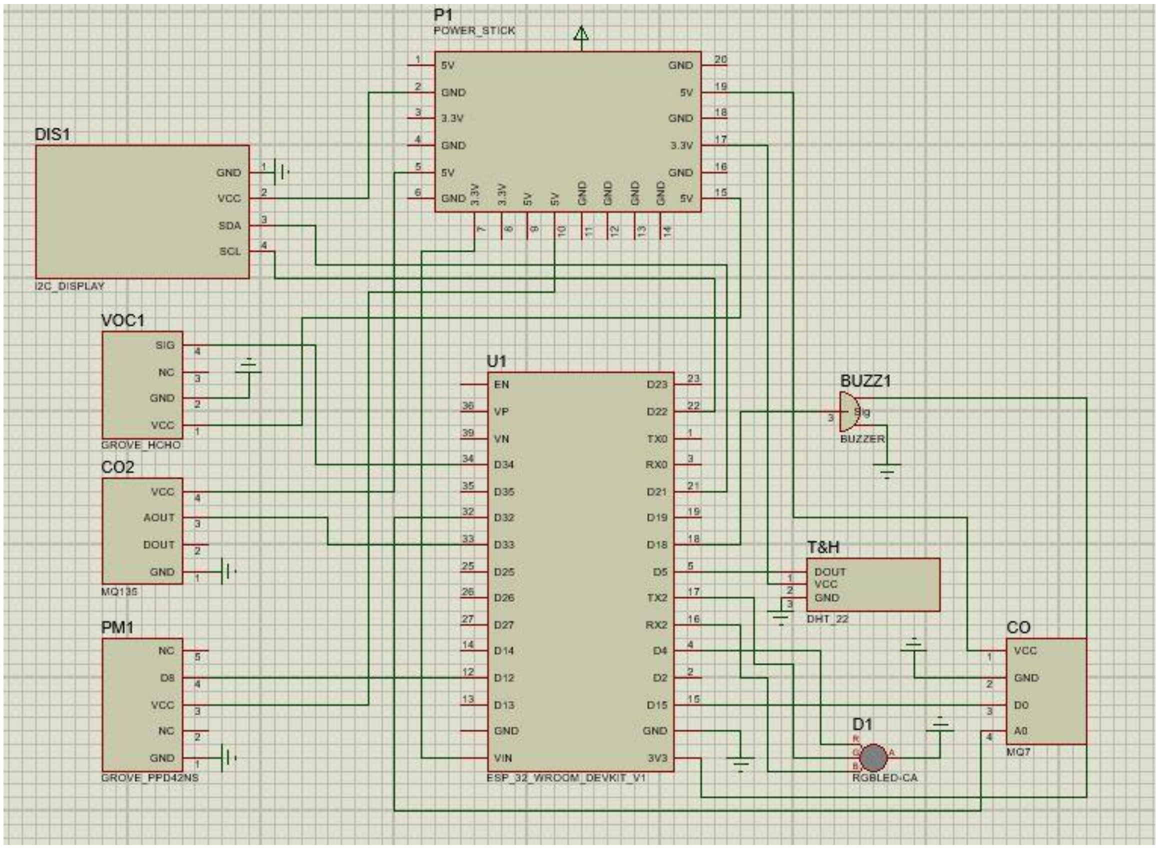

Figure 3.10: Node_1 Schematic design in Proteus 8

We are using same ESP32 pins for Node_2 schematic design as we used in Node_1. But we are not using VOC sensor in Node_2 and dust sensor for Node_2 is GP2Y1010U0F when we have used PPD42NS in Node_1. Figure 3.11 shows our schematic design for Node_2, where MQ7, MQ135, DHT22, GP2Y1010U0F, Buzzer, RGB LED connected with ESP32 development board, a power supply stick is used to give power to all components of the node.

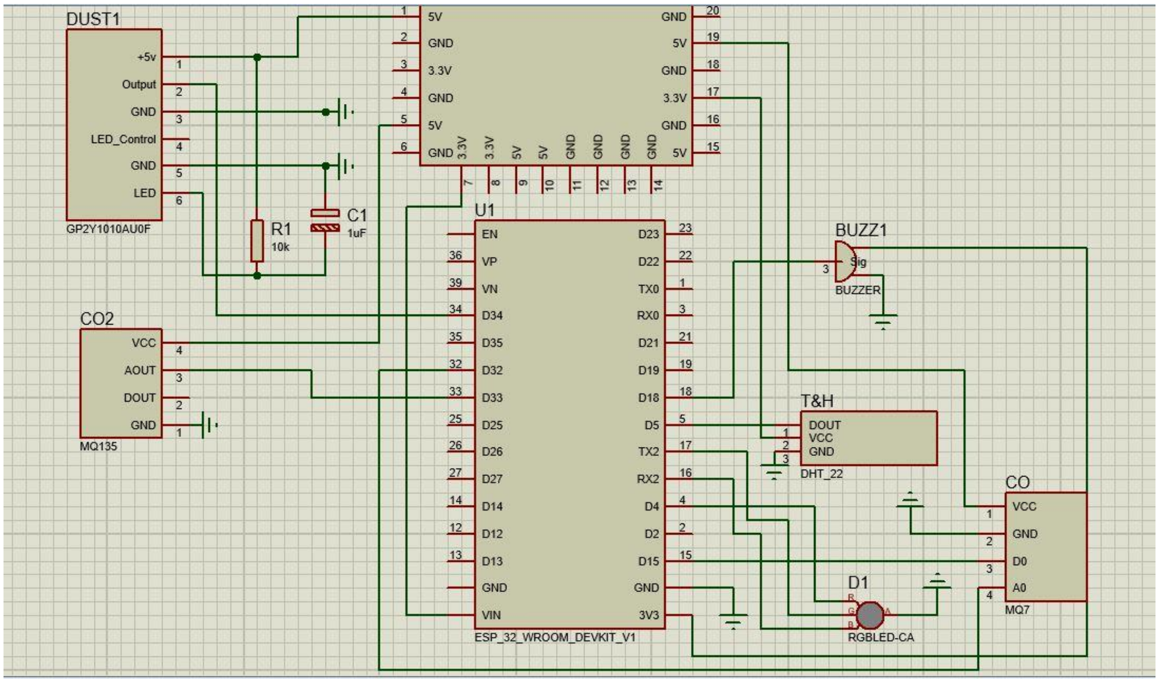

Figure 3.11: Node_2 Schematic Design in Proteus 8

We are not using LCD display for Node_2 and Node_3 contaminant measurement so LCD device were not added to schematic of those nodes. Node_3 is not going to measure any of VOC’s and PM contaminants. Figure 3.12 is the schematic design for Node_3, where MQ7, MQ135, DHT22, Buzzer, and RGB LED connected with ESP32 board, a power supply stick is used like Node_2 and Node_3 to give power to all components.

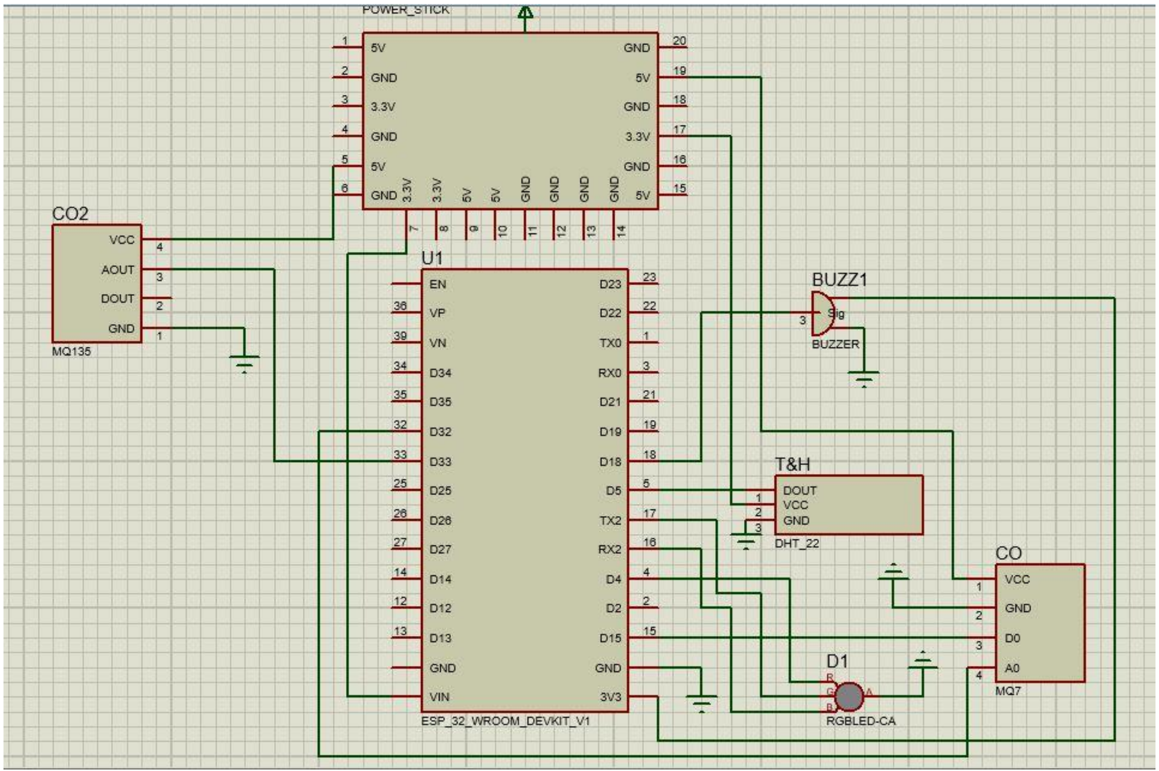

Figure 3.12: Node_3 Schematic Design in Proteus 8

Our PCB designing part is not completed yet, since our nodes have some complex connections the number of jumpers is large. We needed to reduce jumper as low as possible to make a good PCB.

3.6 Bill of Materials

Table 3.5: Components and prices with source note

SL	Components	Qty	Unit Price	Price	Note
1	DHT22	3	490.20	1470.6	DHT22 Sensor Module from techshopbd.com
2	PPD42NS	1	1365.41	1365.41	Grove – Dust Sensor from techshopbd.com *
	GP2Y1010AU0F		1200	1200	GP2Y1010AU0F Optical Dust Sensor from bdspeedytech.com
3	Grove HCHO	1	2045.75	2045.75	Grove – HCHO Sensor from techshopbd.com *
4	MQ7	3	180	540	MQ7 Carbon Monoxide Gas Sensor from bdspeedytech.com
5	MQ135	3	195.24	585.72	Gas Sensor Module (MQ-135) from techshopbd.com
6	LCD Module	1	500	500	LCD2004 I2C Display Module from bdspeedytech.com
7	ESP-32	3	760.78	2282.34	ESP-32 Development Board from techshopbd.com
8	RGB LED	1	120	120	RGB Tri-Color LED Module 10mm from bdspeedytech.com
9	Buzzer	3	60	180	DC-5V Active Buzzer Module from bdspeedytech.com
10	Power supply stick	3	115.5	346.5	Breadboard Power Supply Stick (3.3V/5V) from techshopbd.com
11	AC/DC Power Adaptor	3	100	300	12V 2A Power adapter from bdspeedytech.com
12	Jumper Wires	100+-		250+-	M-M, M-F, F-F jumper wires as required from techshopbd.com
13	Total	125+-		11186.32+- **	

*PPD42NS & HCHO sensor was available for a short time

** Price can be changed over time

CHAPTER 4
RESULTS, WEB SERVER, FUTURE WORK

4.1 Results

Node_1 was our experimental project, as we have succeeded in our experiment after over ten times of failure. We have used LCD display for only Node_1 to show real time contaminant measurement. Figure 4.1 shows 4 real time data in LCD display. During experimenting process of Node_1 we were in ground floor where was no sunlight at all, as we see some contaminants are very high in figure 4.1.

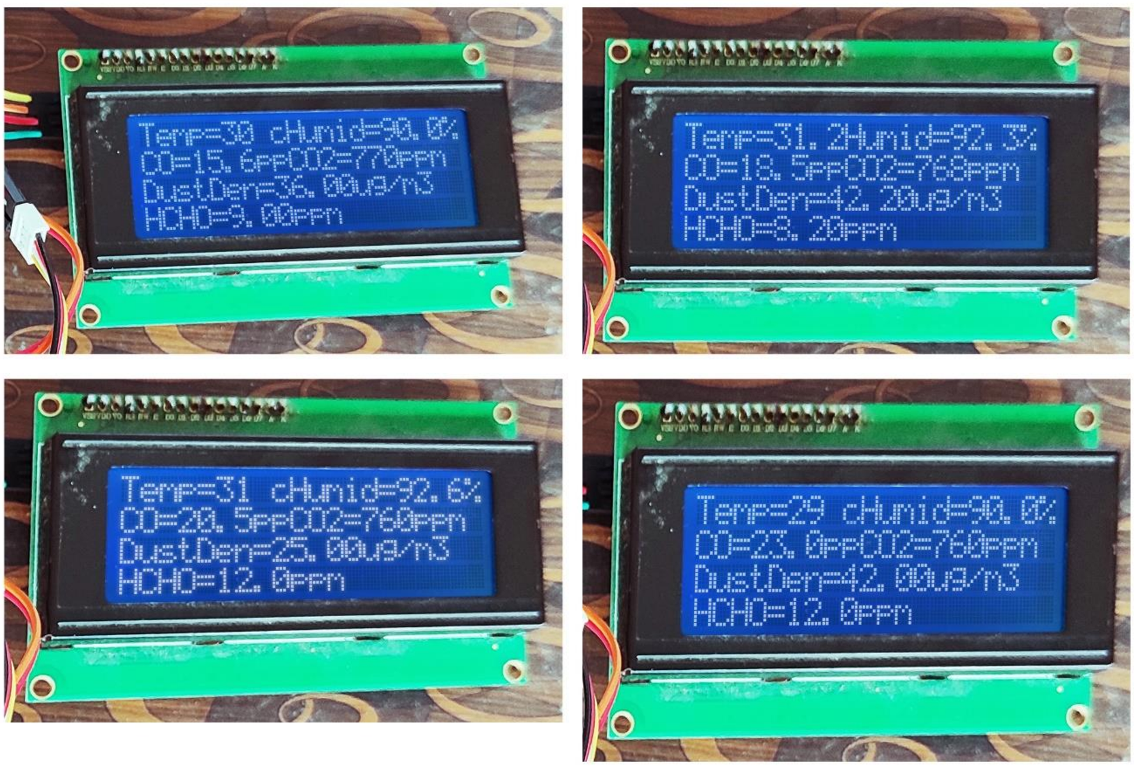

Figure 4.1: Real time contaminant measurement showed in LCD

We have tested our experiment for couple of days, whether all sensors are working well or not. Every sensor needed at least 24 hours preheat to work properly.

4.2 Web Server

In the mean time we have purchased domain and hosting for our project. As we have mentioned earlier ESP32 have default Wi-Fi capability by adding another set of codes we were able to upload real time contaminant data to web server and our data sending to cloud executed successfully. Figure 4.2 shows the (Raw Data) hourly pollutant measurement from Node_1 at 24th September 2020.

Not secure | aqmiot.net/view?fbclid=IwAR14QzPjoo0DjlMXobEdMChCiKb3Q4yQnNk2zruwJ83... Not syncing

AQM IoT Air Quality Monitor and IoT — Home Location About Login

Raw Data — **2020-09-24**

#	MAC	PM	CO_2	CO	VOC	Humidity	Temperature
1	30:AE:A4:99:81:20	36.1	769.9	22.0	9.2	92.4	30.0
2	30:AE:A4:99:81:20	35.1	770.1	23.0	12.2	92.4	30.0
3	30:AE:A4:99:81:20	17.0	770.1	24.1	8.6	92.6	30.0
4	30:AE:A4:99:81:20	58.1	769.8	26.1	8.3	92.7	30.0
5	30:AE:A4:99:81:20	39.7	769.8	27.3	8.3	92.7	29.9
6	30:AE:A4:99:81:20	46.3	769.9	24.7	8.3	92.5	30.1
7	30:AE:A4:99:81:20	0.0	769.8	25.0	6.2	92.4	30.0
8	30:AE:A4:99:81:20	9.6	769.9	24.7	8.3	92.5	30.1
9	30:AE:A4:99:81:20	39.7	770.2	22.8	5.5	92.4	30.1
10	30:AE:A4:99:81:20	32.6	770.1	23.8	6.7	92.4	30.1
11	30:AE:A4:99:81:20	42.2	769.1	22.2	7.5	92.5	30.2
12	30:AE:A4:99:81:20	49.8	769.3	18.7	5.5	93.0	29.9
13	30:AE:A4:99:81:20	39.3	769.4	15.7	10.5	92.7	29.9
14	30:AE:A4:99:81:20	35.7	769.5	19.2	10.8	92.3	30.1
15	30:AE:A4:99:81:20	42.8	769.2	17.3	9.8	92.3	30.2
16	30:AE:A4:99:81:20	23.1	769.2	17.7	0.8	92.4	30.1
17	30:AE:A4:99:81:20	53.8	769.5	20.4	9.8	92.6	30.2
18	30:AE:A4:99:81:20	0.0	769.4	24.7	6.2	92.6	30.1
19	30:AE:A4:99:81:20	46.1	769.3	25.8	9.5	92.4	30.1
20	30:AE:A4:99:81:20	39.5	769.4	20.4	8.3	92.6	30.1
21	30:AE:A4:99:81:20	13.9	769.5	20.9	10.2	92.8	29.9
22	30:AE:A4:99:81:20	37.6	769.4	21.7	8.3	91.7	30.2
23	30:AE:A4:99:81:20	34.9	769.7	21.4	11.8	91.9	30.2

Figure 4.2: Hourly Data (Raw Data) of Node_1 from cloud

4.3 Future Work

As we were able to upload Node_1 data successfully, we are working on an interactive user interface for our cloud data. Figure 4.1 shows our initial concept to view sensor contaminant data on cloud, where Node_1 shows hourly data as we have mentioned in figure 4.2. We have also added Node_2 and Node_3 in our initial web page, but those data were collected from Node_1.

Figure 4.3: Sensors Data in our Website aqmiot.net

Our future targets are- make our web interface much more interactive for users, adding blog on air quality and update the blog with useful information as much as possible, develop an impactful air quality monitoring product which requires lot more experiments. In our website we want to include information about air contaminants and how to reduce.

CHAPTER 5

SUMMARY AND CONCLUSION

5.1 Summary

We are spending over 90% of a day in indoor, without proper ventilation outdoor air pollutants stuck in indoor, which can causes many short and long term diseases. An indoor air quality monitor can help to know about air we are breathing in indoor. In this development project we have develop an experimental device which can show real time indoor air contaminant measurement and upload those data on cloud hourly basis which can be used by user over internet and help to further study on indoor air quality.

5.2 Conclusion

In this report, proposed an air quality monitor using low cost sensors, and we have developed an experimental device which can shows real time data and the device can send data to cloud on hourly basis. Our proposed system have three different nodes, where ESP32 development board used as main board. ESP32 has built-in Wi-Fi module and we were able to upload pollutant reading to the cloud. In this project MQ7, MQ135, PPD42NS, GP2Y1010AU0F, Grove-HCHO, DHT22 are used to measure Carbon Monoxide (CO), Carbon Dioxide (CO_2), Particulate Matters, Volatile Organic Compound (VOC), Temperature and Relative Humidity respectively.

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