

MONITORING INDOOR AIR QUALITY USING SMART INTEGRATED GAS SENSOR MODULE (IGSM) FOR IMPROVING HEALTH IN COPD PATIENTS

Submitted in partial fulfillment of the requirements for the award of
Bachelor of Technology Degree in Biomedical Engineering

By

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**DEPARTMENT OF BIOMEDICAL ENGINEERING
SCHOOL OF BIO AND CHEMICAL ENGINEERING**

SATHYABAMA

**INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)**

**Accredited with Grade "A" by NAAC | 12B Status by UGC | Approved by AICTE
JEPPIAAR NAGAR, RAJIV GANDHI SALAI, CHENNAI - 600 119**

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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of **CAROLINE CHRISelda L (37240017), CHANDANA H (37240018)** who carried out the project entitled “**Monitoring Indoor Air Quality using Smart Integrated Gas Sensor Module for improving health in COPD patients**” under our supervision from **October 2020 to March 2021.**

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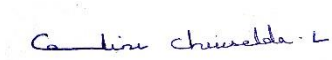
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DECLARATION

We, **CAROLINE CHRISLDA. L (37240017), CHANDANA. H (37240018)** hereby declare that the Project Report entitled **“Monitoring Indoor Air Quality using Smart Integrated Gas Sensor Module for improving health in COPD patients”** done by us under the guidance of **Dr. J. Bethanne Janney, Department of Biomedical Engineering at MedCuore Medical Solutions Private Limited, Royapuram** is submitted in partial fulfillment of the requirements for the award of **Bachelor of Technology Degree in Biomedical Engineering.**

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We wish to express our thanks to all **Teaching and Non-teaching** staff members of the **Department of Biomedical Engineering** who were helpful in many ways for the completion of the project.

BONAFIDE CERTIFICATE

Certified that this project report titled “**MONITORING INDOOR AIR QUALITY USING SMART INTEGRATED GAS SENSOR MODULE (IGSM) FOR IMPROVING HEALTH IN COPD PATIENTS**” is the bonafide work of “**CAROLINE CHRISelda L [REG NO: 37240017], CHANDANA H [REG NO: 37240018]**”, who carried out the project work and internship in our organization under the supervision of **MR. BRITTO SHIBI A**, Product Manager, MedCuore Medical Solutions Private Limited for a period of 6 months (October 2020 – March 2021) in partial fulfilment of Degree of Bachelor of Technology (B.Tech), Biomedical Engineering, Sathyabama Institute of Science and Technology during the academic year 2020-2021.




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ABSTRACT

Technology advancement, industrialization and globalization have been a significant reason for air pollution not only outdoors but also indoors. It may be a surprise to us that we spend about 80% of our time indoors breathing toxic, stale, polluted air, which makes us lethargic and fretful. In contrast to outdoor air, indoor air does not recycle consistently making it trap and build up pollutants released from wood and coal stoves, furniture and building materials, paints and solvents, cigarette smoke and cleaning supplies. The prolonged exposure to these hidden pollutants can prompt acute and chronic respiratory illnesses including asthma, lung cancer, pneumonia, systemic hypertension and chronic obstructive pulmonary disease (COPD). COPD is enduring and is not curable which has been a threat to humanity since ages. According to WHO 250 million people have died due to COPD in 2016. The major cause of COPD is due to airborne particulate matter and other toxic compounds emitted from both indoor and outdoor sources. Outdoor air pollution can be controlled only by acquiring changes in the vast population wherein for indoor, every individual can play a vital role in improving the air quality which enhances the quality of life. The primary purpose of this is to analyse indoor air quality in India, to discuss the significance of Air Quality Index (AQI) and to assess the health impacts due to variation in the amount of temperature, humidity, PM 2.5, CO, CO₂ and NH₃. By doing so healthy individuals can be prevented from the risk of COPD and also diminish the risk to the COPD patients. Indeed, it is very important to monitor the air indoors. This real-time monitoring can be used for detection of pollutant sources and provide information on the variation of pollutant levels throughout the day.

Keywords: Indoor Air pollution, COPD, Air Quality, Integrated gas sensor, real time monitoring

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LIST OF ABBREVIATIONS

ABBREVIATIONS	FULL FORM OF ABBREVIATIONS
WHO	WORLD HEALTH ORGANIZATION
AQI	AIR QUALITY INDEX
PM 2.5	PARTICULATE MATTER (2.5)
COPD	CHRONIC OBSTRUCTIVE POLMONARY DISEASE
CO ₂	CARBONDIOXIDE
NH ₃	AMMONIA
CO	CARBON MONOXIDE
O ₃	OZONE
NO ₂	NITROGEN DIOXIDE
SO ₂	SULPHUR DIOXIDE
VOC	VOLATILE ORGANIC COMPUNDS
LCD	LIQUID CRYSTAL DISPLAY
LED	LIGHT EMMITING DIODE
OLED	ORGANIC LIGHT EMITTING DIODE
DHT	DIGITAL HUMIDITY TEMPERATURE
PPM	PARTS PER MILLION
PPB	PARTS PER BILLION
GSM	GLOBAL SYSTEM FOR MOBILE COMMUNICATION
HEPA	HIGH EFFICIENCY PARTICULATE AIR

CHAPTER 1

INTRODUCTION

1.1 AIR POLLUTION

Air, an invisible form of matter, is the most indispensable fuel for the existence of life on earth. On a daily basis, around 15000 litres of air is pumped in and out of the human's lung. It is vital that the air we breathe is clean and safe. Pure air consists of a definite amount of oxygen and nitrogen but gases such as sulphur dioxide, carbon monoxide, oxides of nitrogen, emission from volcanoes, transport and factory emissions, emission from cooking fuel etc., are continuously released in the air either by natural processes or manmade sources. This leads to the disturbance in the air and results in the most familiar health hazard called Air Pollution. This environmental hazard cannot be seen with our naked eyes but is a silent and prolific killer of human lives.

Air contamination is the disparity or disequilibrium of air quality in both outdoor and indoor environment caused by the incorporation of external materials into the air from natural or anthropogenic sources, causing harm to biological communities in general and humans in particular.

India topped the yearly list of the worst air quality cities in the world, in 2019. According to the 2019 World Air Quality Report, 21 of the 30 most polluted cities in the world were from India. Statistics indicate that the second largest killer in India, accounting for almost 1.3 million deaths per year occurs due to poor indoor air pollution. The lives of people living particularly in rural areas are hugely impacted by the air that they breathe in. It has become necessary for people to keep track of the air that they breathe to prevent any kind of health disaster. Different people can have varying lifestyle, exposing them to varying amount of pollution intake, where they are not generally aware of the hazardous substance present in the air that they breathe.

1.2 OUTDOOR AIR POLLUTION

Outdoor air comprises a dynamic mixture of particles, chemicals and biological substances originating from anthropogenic and natural sources that

exists in the outside environment from ground level to several miles above the earth's surface. Fossil fuel combustion and vehicle emission cause the major part of outdoor air pollution releasing major pollutants like particulate matter, carbon monoxide, nitrogen oxides, sulphur dioxide and polyaromatic hydrocarbons.

Despite the outdoor air being one of the major sources of the indoor particulate matter, other factors must be considered because particle mass and particle size quantities in the indoor atmosphere are substantially different. Indoor air pollution levels, on the other hand, are often 2 to 5 times higher than outdoor levels, with some reaching 100 times higher. To put it another way, the temperature indoors is often worse than the weather outdoors.

1.3 INDOOR AIR POLLUTION

Indoor air pollution relates to the physical, chemical and biological characteristics of indoor air inside a residence, building or organisation or a commercial facility. Indoor air quality is a problem in developing countries, where energy efficiency developments often make homes comparatively airtight, reduce airflow and increase pollutant levels. Indoor pollution problems can be subtle and do not often produce readily identified health effects. Various conditions are responsible for indoor air pollution in rural areas and urban areas.

Rural areas in developing countries are the most vulnerable to indoor emissions, with 3.5 billion people currently relying on conventional fuels including firewood, charcoal, and cow dung for cooking and heating. The levels of indoor emissions in conventional fuel-burning homes are concerning. In the enclosed space of the house, burning certain fuels emits a considerable volume of smoke and other air contaminants, resulting in high exposure. Women and children are by far the most susceptible individuals who spend significant time confined and are more prone to smoke. Indoor air quality in developing countries was named one of the four main serious global environmental issues by the World Bank in 1992. Indoor pollutant levels often surpass existing WHO standards and permissible levels on a daily basis. Although a variety of new chemical agents have been found in bio fuel smoke, particulates, carbon monoxide, polycyclic organic matter and

formaldehyde are the four most serious contaminants. Unfortunately, no scientifically accurate testing has been performed in rural and low urban indoor settings.

In urban environments, exposure to indoor air emissions has increased due to several factors, including the construction of more closely enclosed structures, decreased insulation, the use of synthetic materials for construction and furnishing, and the use of chemical chemicals, pesticides and household care products. Indoor air pollution may begin inside the building or be removed from the outside. Other than nitrogen dioxide, carbon monoxide and lead, there are a variety of other contaminants that influence the quality of the air in the enclosed area.

1.4 HARMFUL GAS AND ITS SOURCE OF EMISSION

Indoor environment can have lower health status than elsewhere. Some household materials, for example, emit gases such as volatile organic compounds (VOCs). Headaches, fatigue, sore eyes and throat irritation are all possible side effects. Children, who breathe quicker than adults and inhale more air, may be particularly vulnerable to indoor air pollution. It may be especially harmful to babies who are close to the ground, where strong chemicals linger in the air.

A number of indoor air pollutants like NO_x, SO₂, O₃, CO, volatile and semi-volatile organic compounds (VOCs), PM, radon and microorganisms have been identified. Most of these toxins (e.g. NO_x, SO₂, O₃, and PM) are common indoor and outdoor surroundings, though others are common in outdoor environments. Such air contaminants can be inorganic, organic, biochemical or even radioactive. The adverse reactions of these air contaminants can vary from person to person based on the toxicity, concentration and exposure period of the pollutants.



Fig 1.1 Sources of Indoor Air Pollutants

➤ **Paints and Indoor Air Pollution**

Paints bring brightness to the surroundings we live in and protect wood and metal from rotting and corroding respectively. However, these colourful paints can also have a negative impact on our well-being. The biggest threat to health and the environment is from lead-based paints which continue to be part of the Indian market. VOC's emitted as gases released from variety of chemicals in Paints and varnishes contribute majorly to indoor air pollution which may have short- and long-term adverse health effects. On reaction to sunlight, VOC's convert to ozone and produce smog in the atmosphere. Though most of the paint industries contend that airborne emissions are safe in well ventilated areas, these optimal conditions are never attained in real life. In indoors, the heavy metals in paint, such as cadmium, mercury, lead or chromium, tend to scatter their residues and last for a longer period. Long term health effects may occur from exposure to these heavy metals, either by respiration or direct contact.

➤ ***Cleaning Products and their health effects***

Some household cleaning products contain toxic chemicals that can cause skin problems and irritation to the respiratory tract if inhaled or touched. This is especially true for those who have skin or breathing issues. Allergies may be aggravated by certain products. Those containing ammonia and chlorine may be particularly irritating to asthma patients.

➤ ***Second hand smoke***

People who live in an environment where someone smokes are more susceptible to ear infections, pneumonia, bronchitis, and coughs. Asthmatic individuals can have more regular and serious attacks. Smoke inhalation can cause asthma in individuals who has never had symptoms before. People may be harmed by third hand smoke, which is a poisonous substance that lingers in clothing, cushions, and furniture. This is particularly true when they work or move in the hallway.

➤ ***Cooking fuel***

In India, the fuel used for cooking depends on habit, availability of resources and also the affordability rates. In 2016, The World Health Organization reported that 59% of the Indian population used primary fuels like wood, charcoal, and kerosene for cooking. Using these resources for cooking in household premises increases the chances of contracting a range of diseases. Comparatively women are more exposed to the pollutants like smoke and oil vapours released by the cooking fuels than men which elevate the risk of respiratory infection and also majorly cause birth defect.

Gas stoves that have been improperly built or vented will emit dangerous gases into the house. Carbon monoxide can make people tired even at lower concentrations. Symptoms like nausea, headaches, confusion, and even death may occur at higher concentrations. Nitrogen dioxide can irritate the lungs, particularly in children. It must be ensured that the burners are well calibrated such

that the flame tips are still blue. A vacuum with a filter that blows outside can be used to vent the toxic gases which keeps aggravating due to cracks and poor ventilation in kitchens.

➤ ***VOC emitting compounds***

Poorly ventilated homes appear to absorb odours from the kitchen and trap the air contaminants within our surrounding. This prompts the use of perfumes, deodorants, and scented candles to enhance the living in our homes. All of these include numerous powerful chemicals. Air fresheners include toxic substances such as formaldehyde, benzene and VOCs, in some cases causing headache, asthma and even cancer. Chemicals like VOCs and phthalates are also present in perfumes and similar products. The Scented Goods containing VOCs react with sunlight and the other atmospheric chemicals to form carcinogenic ozone emissions. These then generate a range of secondary air contaminants such as formaldehyde and ultra-particulate matter, causing significant heart and lung problems. On the other hand, Phthalates found in fragrances are associated to cause health conditions such as headaches, skin, nose and throat inflammation, nausea, asthma, sinus, hormonal and respiratory complications.

➤ ***Building materials***

Particulate wood furniture is also mainly accountable for emissions that are close to those of volatile organic compounds, owing to the use of volatile organic compound-emitting adhesives. The use of building insulation has also been linked to the release of volatile organic compounds. Asbestos in sheets used in building construction produces small dust molecules. Similarly, silicon particles can be present in large quantities in brick and cement buildings. The advancement in technologies has resulted in the digitalization of homes. Computers, smart phones, iPads and printers are now found in almost every home. These have been linked to elevated ozone levels in the homes. In foam-containing furniture and electronic devices, polybrominated diphenyl ethers (PDBEs) are used as fire retardants.

PentaPDBEs and DecaPDBEs are released in trace amounts, contributing to household air pollution.

1.5 CHRONIC OBSTRUCTIVE PULMONORY DISEASE

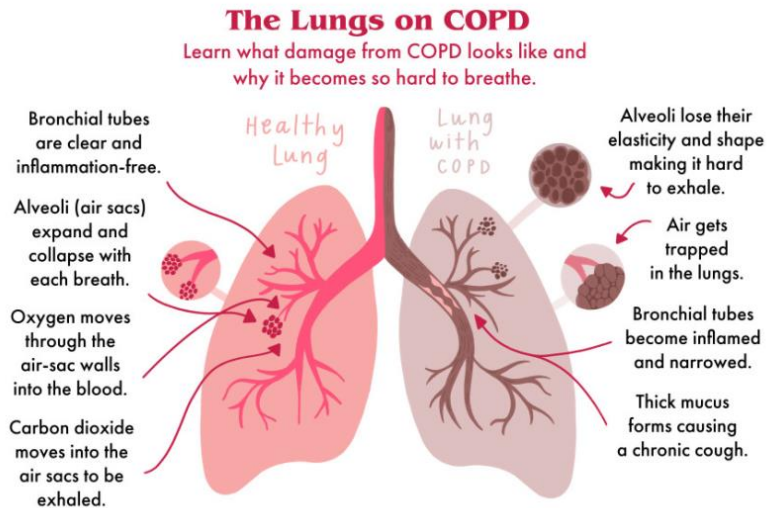


Fig 1.2 Comparison of Healthy lung and COPD lung

Chronic Obstructive Pulmonary Disease (COPD) was India's second leading cause of death after cardiac ailments in 2017. The number of incidents of COPD was higher than road accidents or suicides in 2016. Also, it took more lives than diabetes, malaria, tuberculosis and breast cancer combined. COPD is characterized by the airway inflammation of the lungs leading to the deterioration of air sacs resulting in difficult breathing. This heterogeneous, incurable and progressive disorder is India's most underrated and overlooked condition.

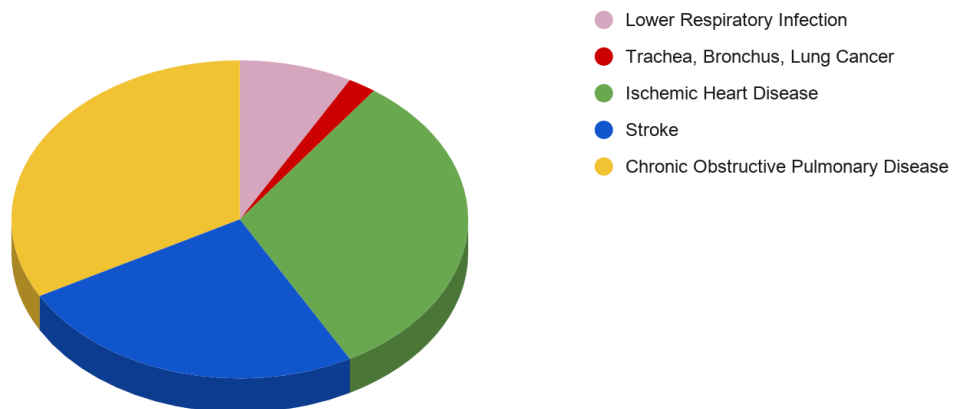


Fig 1.3 Indoor Air Pollution Attributable Deaths in India by Disease

➤ ***Air Pollutants – Cause of COPD***

Air pollution is a combination of pollutants found within enclosed area and in ambient environment as well as pollutants. Emissions released from transport, construction of roads and unplanned distributions of industries in the outdoors have contributed to cause COPD. However, evidence on COPD caused due to the indoor pollutants in India is limited.

An increase in the emissions of toxic pollutants in the indoors result due to the residential homes which lie adjacent to factories and industries which release harmful fumes and chemicals. The toxic pollutants such as particulate matter (PM_{2.5}, PM₁₀) and green-house gases like ozone (O₃), sulphur dioxide (SO₂), nitrous oxide (NO₂), etc were found in number of locations. Burning of fossil fuels adds up to pollute the atmosphere. Tobacco and cigarette smoke has been recognized as an enclosed pollutant, with increasing health risks.

The major levels of indoor pollutants in residential areas include emissions from cooking (biomass fuels), smoking, burning of mosquito coils, cigarettes, incense sticks, cleaning agents, paints and varnishes etc. Allergens from dust mites, cockroaches, fungi, pollens, pets like cats/dogs, rodents are common in households. The household sector is a non-point source: each household includes many individual 'polluters' with modest contributions but together are a bigger problem. This leads to the deterioration in the quality of life.

1.6 SIGNIFICANCE OF AQI

The Air Quality Index (AQI) is a measurement of average pollution levels. It warns the people about how toxic and contaminated the air is. It provides a perspective on the adverse health effects that arises in a few hours or days after being exposed to unhealthy air. Air Quality Index is an indicator that allows every individual to quickly understand the current status of air quality. It converts the complex air quality data of various pollutants/contaminants into a numerical value (index value) and terminology represented by different colours. A significant number of people are subject to serious health problems with a rise in AQI.

In developing countries like India where citizens are not very familiar with scientific terms and units of measurement (such as PPM/PPB or $\mu\text{g}/\text{m}^3$), AQI is extremely beneficial. Thus, with each figure and colour reflecting an inferred category of health risk, the AQI simplifies the perception of air quality by decoding it in unit numbers and colours as shown below.

AQI Category	PM10 $\mu\text{g}/\text{m}^3$ 24 Hr	PM2.5 $\mu\text{g}/\text{m}^3$ 24 Hr	NO₂ $\mu\text{g}/\text{m}^3$ 24 Hr	O₃ $\mu\text{g}/\text{m}^3$ 8 Hr	CO mg/m^3 8 Hr	SO₂ $\mu\text{g}/\text{m}^3$ 24 Hr	NH₃ $\mu\text{g}/\text{m}^3$ 24 Hr	Pb $\mu\text{g}/\text{m}^3$ 24 Hr
Good (0-50)	0-50	0-30	0-40	0-50	0-1.0	0-40	0-200	0-0.5
Satisfactory (51-100)	51-100	31-60	41-80	51-100	1.1-2.0	41-80	201-400	0.6-1.0
Moderate (101-200)	101-250	61-90	81-180	101-168	2.1-10	81-380	401-800	1.1-2.0
Poor (201-300)	251-350	91-120	181-280	169-208	10.1-17	381-800	801-1200	2.1-3.0
Very Poor (301-400)	351-430	121-250	281-400	209-748	17.1-34	801-1600	1201-1800	3.1-3.5
Severe (401-5000)	430+	250+	400+	748+	34+	1600+	1800+	3.5+

Table 1.1 National Air Quality Index

Here it can be shown if the AQI range is between 0-50 and is shown in dark green colour, which means the data are satisfactory and shown in the greenish colour when the AQI range is 51-100. Then, where the data level reaches 101–200, it would suggest that the area is mildly unsafe and then if it exceeded 201 this indicates that the environment has been badly contaminated and the AQI range is very low and heavily polluted and healthy for humans when it reached the maximum of 301–400.

AQI Category	Associated Health Impact
Good (0 to 50)	Minimal impact
Satisfactory (51 to 100)	May cause minor breathing discomfort to sensitive people
Moderately Polluted (101 to 200)	May cause breathing discomfort to the people with lung disease such as asthma and discomfort to people with heart disease, children and older adults
Poor (201 to 300)	May cause breathing discomfort to people on prolonged exposure and discomfort to people with heart disease
Very Poor (301 to 400)	May cause respiratory illness to the people on prolonged exposure. Effect may be more pronounced in people with lung and heart diseases
Severe (401 to 500)	May cause respiratory effects even on healthy people and serious health impacts on people with lung/heart diseases. The health impacts may be experienced even during light physical activity

Fig 1.4 AQI category and associated health impacts

CHAPTER 2

LITERATURE REVIEW

A gas detector is used to detect leakage of gases and provide appropriate alarming signals. Divya et.al (2018) developed a gas monitoring system to monitor the conditions of washrooms and industries. Hydrogen sulphide, methane, ammonia, carbon monoxide and nitrogen oxides are the majorly produced gases in these areas and make the place unhygienic and unhealthy. Sensors used included MQ-4, TGS-2602 and MQ-136 to monitor the respective gases. Depending on the PPM level of the gases, they were classified into medium and high-level gases. On “medium” indication fan and exhaust fans are being turned on whereas on “High Level” indication an SMS is sent to the authority through GSM module.

Hicham Ajami et.al (2019) proposed a regulatory ontology structure for COPD patients and validated its framework. Their work provides a modern view of telemedicine and remote care technologies that, through an innovative decision-making methodology, can facilitate individual self-management services such as general health status and also their indoor air parameters such as temperature, humidity, dust mites and several gases. Thus monitoring vital signs and environmental conditions had an accuracy rate of 89 percent, while dietary information and physical movements had an accuracy rate of 87 percent. They then carried out several experiments to demonstrate the use of the model. Then vital signs, activity, and environmental conditions of the patient were all constantly tracked.

P.V. Upadhyay (2019) developed a monitoring system to monitor the pollution in Ahmadabad city as it ranks high in level of PM 2.5 and also monitored the levels of noise pollution. The equipments were installed at different places and studies were carried out for two days each one hour. Investigation revealed that Chandola Lake was the most polluted place. Restaurants, shops and bakeries in Bhopal had 8 times more PM content than the ideal standards. Kalupar Railway

station was the busiest railway station and consequently was prone to more noise and air pollution. This work gave information to people regarding their surrounding air quality.

Utkarsha Pathak et.al (2019) showed that indoor air emissions due to solid biomass fuels raised the risk of COPD and Chronic bronchitis relative to non-biomass fuel. The probability of COPD was higher in Africa, Asia, South America, Europe and North America. The majority of COPD was observed in females living in low and middle-income countries. Studies have shown that there is an urgent need for large-scale public health action to reduce the prevalence of COPD and CB in low-middle-income countries. This can be accomplished by offering more effective methods for the total combustion of biomass fuel. Preventive steps should also be taken to minimize this risk in these communities.

Sarath Raju et.al (2019) found out that indoor air pollution, from sources that include indoor tobacco smoke, burning of solid fuels, and noxious gases from cooking and heating, is associated with greater risk for chronic lung disease development and respiratory morbidity worldwide. The author elaborated the importance to raise awareness on the common sources of pollution among clinicians, policy makers, and patients with chronic respiratory disease alike, to improve health education and promote efforts that can reduce pollutant exposure across households and address environmental health disparities.

H. Nigam et.al (2019) proposed the idea of assistive technology for E-mail and SMS notification used in real time to provide information of AQI. The parameters measured by this assistive technology in the indoors included Temperature, Humidity, heat index, CO and CO₂ using electrochemical gas sensors and infrared sensors along with ESP-8266 Wi-Fi module for AQI data transmission. The captured data is sent to the building occupants via SMS or E-mail and the OLED display shows the Air quality and Heat Index. The next live data was automatically updated.

The IoT-based method for monitoring IAQs was developed and analysed by Sivasankari et.al (2017) using the model Raspberry Pi. Parameters like temperature, NO₂, CO and smoke concentrations were used in this analysis. The measurements were performed by MQ series cameras, NO₂ sensor Mics 2714, LM-35 and the sensor DHT11. The device was also supplemented with an analog to digital converter so that the sensors can communicate through 8 different channels with the Raspberry pi board. This device produced an alert to indicate a high emissions concentration, such as an alert against atmospheric pollution.

Construction and design of a handheld, affordable indoor surveillance device were mainly concentrated by Tiele et.al (2018). The research has been conducted on certain important indoor air parameters such as tone, light, CO, CO₂, VOC, PM₁₀, PM_{2.5}, RH and temperature. The experiments were carried within and as well as outside. In order to approximate the total IEQ percentage, the authors specified an Indoor Quality Index (IEQ).

R. K. Kodali et.al (2020) reported indoor air emissions can be produced in a variety of forms, and there are many pollutants found in the indoor environment. Using the Internet of Things, a wireless air quality control system is set up, which sends warnings to consumers via the Internet, when the concentration of contaminants detected falls above a safer limit. The system's warnings can be received on a mobile phone from any place, regardless of whether it is linked to the Internet. The NodeMCU Device board v1.0, which contains an ESP8266 Wi-Fi activated chip, was used as the microcontroller.

Chattopadhyay M et.al (2021) developed a simple method for detecting pollutants and controlling impurities with a portable filtering system. The detection or monitoring system is connected directly to the sensor outputs and includes a local display as well as a remote monitoring controlled by the Internet of Things. The control module consists of a series of connected HEPA filters and activated charcoal filters along with the ATmega328P microcontroller.

CHAPTER 3

AIM AND SCOPE

3.1 AIM

The aim of our proposal is to build a low cost yet a quantitative and qualitative integrated gas sensor module for monitoring the amount of temperature, humidity, PM 2.5, CO, CO₂ and NH₃ so as to make individuals aware and bring forth the strategies to minimize the effects of indoor air pollution.

3.2 EXISTING SYSTEM

Air quality monitors available in the market give merely the air quality of the surroundings and do not specifically emphasize on the corresponding health impacts. These products measure only a few parameters and have a significant impact on the market due to their high cost. The sensors available in the market are not generally developed for indoor purposes and do not store the data via cloud platform.

All products that already exist will have an outer casing which consists of plastic and other hazardous materials, which are the primary source of air pollution and may cause serious health issues.

3.3 PROPOSED SYSTEM

Our project proposes to find an intriguing solution to monitor indoor air quality for maintaining the healthy quality of life. The proposed product detects monitors, assesses, evaluates and displays the real time data of the particles that are present inside a living area quantitatively and also notifies in view of health parameters. By implementing a cloud server where data collected are sent to Thing speak platform, data can be viewed and analysed in real time as well as throughout the entire monitoring period. The AQI values of various pollutants are being displayed and therefore educating the people about the amount of pollutants they are being exposed to. LED indicator alarms the people about the condition of air quality depending on the amount of pollutants present in the environment.

Biodegradable plastics are a safe option because they do not pose adverse effects to human health and is used for casing and protection of IAQ monitor.

3.3.1 Advantages of Proposed System

3D printing of enclosures offers freedom of design, allowing the manufacturer to print a prototype or final component in a couple of hours. In comparison to conventional production processes it is much cheaper. 3D printed enclosures provide an easy way to validate shape and fit; and certain fabrics that are ideal for printing enclosures for end-use applications.

3.4 SCOPE AND APPLICATION

The indoor air quality monitoring system in the living room, the office buildings, shopping centres, hospitals and other indoor areas help to create a cleaner atmosphere and keep the AQI under control. By matching real-time data on air quality with normal and optimal settings, people will, in advance, encourage proper ventilation; monitor the use of goods that emit unhealthy contaminants and even keep temperature and humidity levels within a comfortable range.

CHAPTER 4

MATERIALS AND METHODS

4.1 HARDWARE COMPONENTS

4.1.1 Arduino UNO

Arduino is a single-board microcontroller which renders incorporating electronics in multidisciplinary activities fully available. The hardware is a basic open source hardware board based on an 8-bit Atmel AVR or a 32-bit Atmel ARM microcontroller. On the microcontroller, the device consists of a common programming language compiler and a boot loader.

Arduino is an open-source prototype framework of simple hardware and software. It is made up of a programmable circuit board (also known as a microcontroller) and ready-to-use software labelled as Arduino IDE (Integrated Development Environment), which is used to write and transfer programming code to the physical device.

➤ Specification

- Microcontroller: ATmega328
- Operational Voltage: 5V
- Input Voltage: 7-12V
- Input Voltage: 6 - 20V (range)
- 14 Digital I/O Pins of which 6 provide PWM output
- Input Pins (analog): 6
- DC Current: 40mA per I/O Pin
- DC Current: 50mA for 3.3V for each Pin
- Flash Memory: 32 KB (ATmega328)
- SRAM: 2 KB (ATmega328)
- Clock Speed: 16 MH

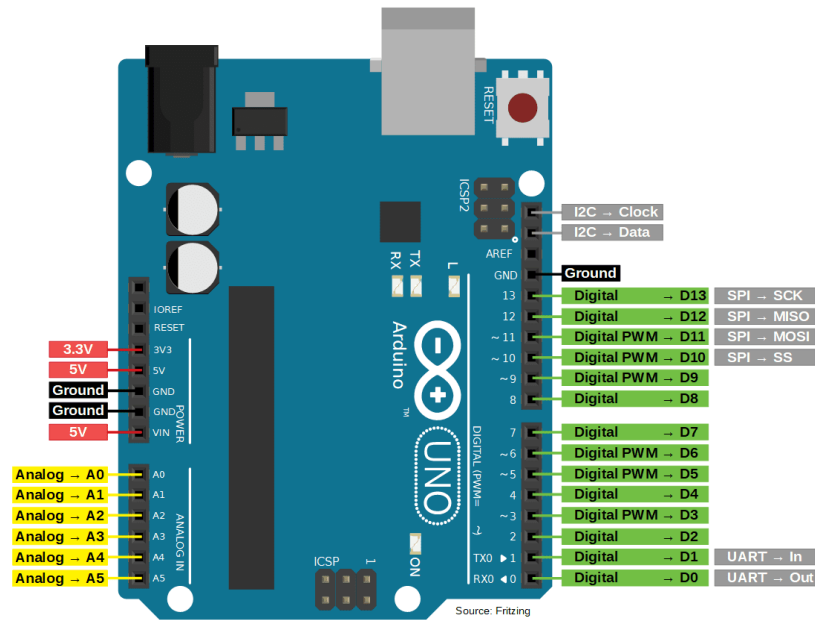


Fig 4.1 Arduino Uno

4.1.2 NODE MCU- ESP8266

The ESP8266 is designed by Espressif Systems microcontroller. The ESP8266 itself is a free Wi-Fi network solution which can also operate self-contained application as a connection from existing micro controllers to Wi-Fi. This module has a USB connector and an extensive selection of pin-outs. You can attach Node MCU devices to a laptop with a micro USB cable and flash it easily; much like Arduino It is also breadboard compatible.

➤ Specification

- Voltage: 3.3V.
- Wi-Fi Direct (P2P), soft-AP.
- Consumption of current: 10uA~170mA.
- Attachable flash memory: 16MB max (512K normal).
- Integrated TCP/IP protocol stack.
- Processor: Ten silica L106 32-bit.
- Speed of the processor: 80~160MHz.

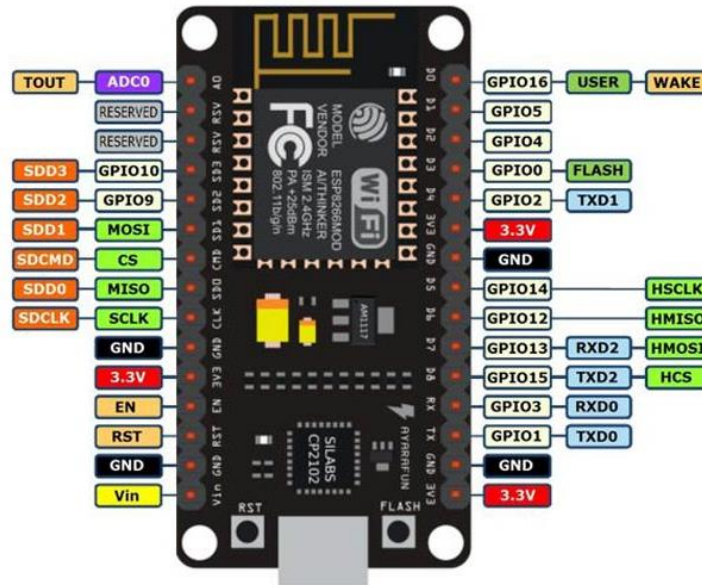


Fig 4.2 Node MCU- ESP8266

4.1.3 Liquid Crystal Display

Liquid crystal displays (LCDs) include materials that incorporate the properties of liquids and crystals. Instead of possessing a melting point, they have a temperature range within which the molecules are about as mobile as they would be in a liquid, but they are grouped together in an orderly structure similar to a crystal. The LCD consists of two glass plates, on which the liquid crystal content is braided with sand. The inside surface of the glass plates is coated with translucent electrodes that identify the characters, objects or patterns to be shown. Polymeric layers are found between the electrodes and the liquid crystal, which makes liquid crystal molecules capable of maintaining a given orientation.

Each of the polarisers is pasted out of the two glass plates. These polarisers will tilt the light rays going through them at a certain angle, in a certain direction. When the LCD is off, the light rays are rotated by the two polarisers and the liquid crystal, so that the light rays come out of the LCD without any direction, and thus the LCD becomes translucent. If appropriate voltage is applied to the electrodes, the molecules of liquid crystal will be oriented in a certain direction. The light rays going through the LCD would be rotated by the polarisers, which would activate/highlight the desired characters.

➤ Specification

- Display Mode: STN, BLUB
- Display Format: 16 Character x 2 Line
- Viewing Direction: 6 O'clock
- Input Data: 4-Bits or 8-Bits interface available
- Display Font : 5 x 8 Dots
- Power Supply: Single Power Supply (5V±10%)
- Driving Scheme : 1/16Duty,1/5Bias
- Backlight (Side) : LED (Blue)

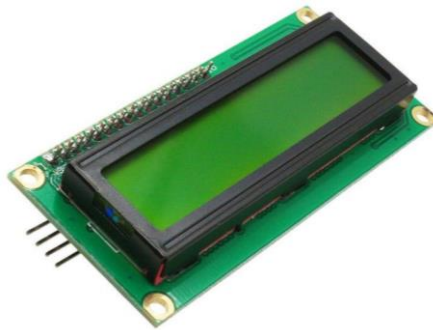


Fig 4.3 Liquid Crystal Display

4.1.4 Light Emitting Diode

Light Emitting Diode is a two lead light emitting device consisting of a PN junction. It is an active semiconductor component similar to that of the normal diode. The capability of emitting light in different colours sets apart the LED from a normal diode. The basic principle is when voltage is applied to the leads, the cathode and anode in a correct polarity; electrons recombine with holes in the junction which release energy in the form of photons by a process called electroluminescence. Corresponding to the energy of the photon and the band gap of the semiconductor, determination of the colour is achieved.

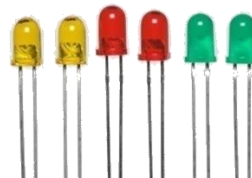


Fig 4.4 Light Emitting Diode

4.1.5 DHT 11 – Temperature and Humidity sensor module

The DHT11 is a low-cost Humidity and Temperature Sensor that outputs a calibrated digital signal with long term stability and durability. The DHT11 can be connected to any microcontroller, such as an Arduino or a Raspberry Pi, and have immediate performance. It is quite easy to use, and libraries and sample code for Arduino and Raspberry Pi are accessible.

➤ Working Principle

DHT 11 has 3 main components: humidity sensing component, NTC temperature sensor, 8-bit microcontroller.

Humidity sensing component has 2 electrodes and a substrate to hold the moisture or humidity. So, when the humidity or moisture changes, the conductivity of the substrate will change or the resistance between the 2 electrodes changes. The change in resistance is processed by the IC and makes it read by the microcontroller.

Thermistors are variable resistors that change in resistance with respect to temperature. Thermistor are made by ceramics or poly ceramics (to provide large changes in resistance ,by small changes in temperature).To use the sensor, only three connections are required: Vcc, Gnd, and Output. It has good efficiency and outstanding long-term stability due to the unique optical signal acquisition technique and the temperature and humidity sensing technology.

➤ Specification

- Maximum capacity : 3.3~5.5V DC power supply
- Output: 4 row pins
- Measuring range: 20 to 90 percent RH of humidity and 0 to 50°C temperature.
- Precision: +-5 percent RH humidity, +-2°C temperature;
- Resolution: Humidity of 1%, Humidity of 1°C;
- Interchangeability: fully switchable
- Stability for the long term: <±1% RH/year



Fig 4.5 DHT Temperature and Humidity Sensor Module

4.1.6 PM2.5 - GP2Y1010AU0F Dust Smoke Particle Sensor

The infrared emitting diode (IRED) and the phototransistor are diagonally arranged in this unit. GP2Y1010AU0F Module is often used for sensing dust particles in the atmosphere and is often referred to as an optical air quality sensor. It's a lot smaller in scale. It detects the reflective light of dust particles. In particular, it is effective to detect very small particles such as tobacco smoke. In addition, smoke can be distinguished from house dust by the pulse pattern of the output voltage which is widely used in air purifier units. The sensor consumes very less amount of current (20mA max, 11mA typical) and can be powered with upto 7VDC. The sensor gives analog voltages as the output which is proportional to the measured dust density.

➤ Working Principle

The air goes through the air inlet where repeated toggling IR LED light falls on the air. The IR light will illuminate the dust particle present in the air. Then, a scattered light signal is produced. The scattered light is detected by the light detector. The output is amplified by multiple signal amplifier circuit. Then the amplified light signal is processed to get concentration of dust particles in air. At the end the optical dust sensor produces an analog voltage on Vo pin according to the concentration of dust particles.

➤ Specification

- Strength supply: DC5 ± 2V

- 0.5V / (0.1 mg/m³) Sensitivity
- Minimum particle detection level: 0.8 m
- Good air tension: 0.9V.
- Small current intake (I_{cc}: MAX. 20 mA)
- The photometry of only one pulse will detect the presence of dust
- May differentiate between smoke and household dust

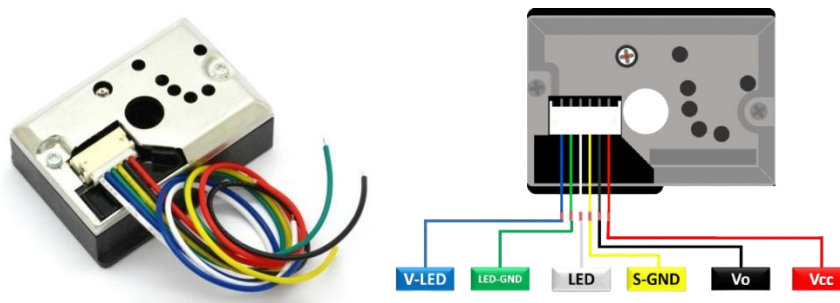


Fig 4.6 PM2.5 - GP2Y1010AU0F Dust Smoke Particle Sensor

4.1.7 Gas Sensor

The principle working of the gas sensor depends on the chemiresistance for conducting current. Tin oxide (SnO₂), a n-type semiconductor is the most commonly used chemiresistor due to the availability of free electrons. Normally air around us contains more oxygen than combustible gases. Hence free electrons are being attracted by the oxygen and are pushed to the top layer of SnO₂ which results in zero output current. Since toxic gases are present in the air, there will be lesser amount of oxygen and hence lesser attraction of free electrons towards oxygen resulting in flow of current.

4.1.7.1 MQ – 135 (Air Quality Sensor)

Digital and analog outputs are obtainable on the MQ135 Gas Sensor module for Air Quality. Sensitive content of the MQ135 gas sensor is SnO₂, which has a lower conductivity in clear air. When the target combustible gas exists, the conductivity of the sensors is higher along with the increase in the concentration of the gas. The MQ135 gas sensor is highly sensitive to ammonia, sulphide and

benzene, and is also sensitive to smoke and other toxic gases. It is cost effective and ideal for various applications. Detects noxious gases in the surrounding atmosphere and is used by the family. Apply to ammonia, aromatics, sulphur, benzene vapour and other toxic gases/smoke, gas detector, concentration spectrum verified: 10 to 1000 ppm.

➤ *Specification*

- Required voltage: 5V DC
- Required current: 150mA
- DOUT: output from TTL
- AOUT: Analog outcomes
- Period of preheat over 20s
- Size: 32mm x 22mm x 27mm (HIGH 27mm)

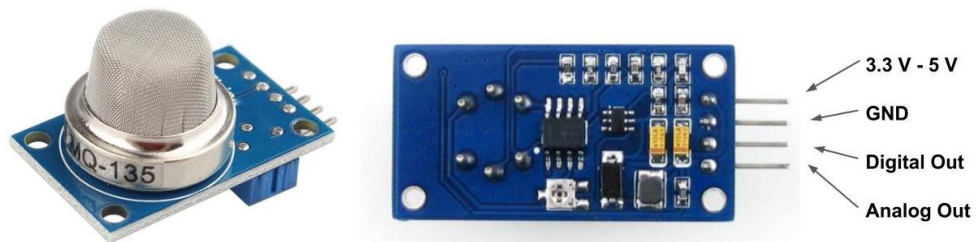


Fig 4.7 MQ – 135 (Air Quality Sensor)

4.1.7.2 MQ – 7 (Carbon Monoxide Sensor)

The concentration of Carbon Monoxide in the air can be detected by using MQ – 7 gas sensors and the output is displayed as an analog voltage. The sensor has a longer life span and a better stability.

➤ *Specification*

- Dimensions: 35mm / 22mm
- Preheating: $5 \pm 0.2V$ (AC · DC)
- Current operation: 140mA
- Range of detection: 10-1000ppm
- Clean air voltage: $\leq 1.5V$

- Sensitivity: $\geq 3\%$
- Temperature of operation: $-10 \sim 50^{\circ}\text{C}$ (Nominal temp 20°C)

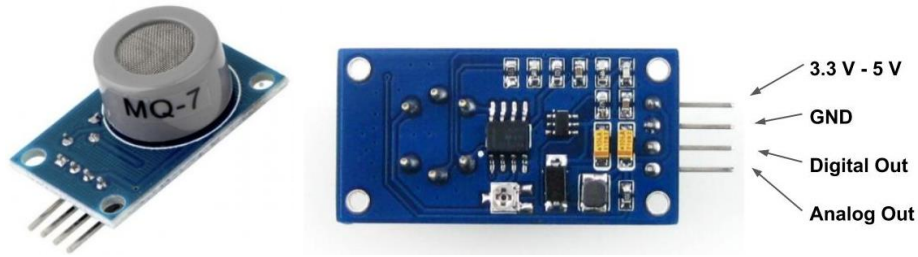


Fig 4.8 MQ – 7 Gas Sensor

4.2 SOFTWARE USED

4.2.1 Arduino IDE

A cross platform framework (for Windows, macOS and Linux) written with functions C and C++ is an Arduino Integrated Development Environment (IDE). It is used for writing and uploading Arduino compatible applications, but also for other developer boards with the support of third-party core systems.

The IDE source code is released under the GNU General Public License, version 2. The Arduino IDE uses special code structuring guidelines to support the languages C and C++. The Arduino IDE supplies a wiring project software library that provides a number of common input and output procedures. User-written code only needs two simple functions to start the sketch and the main program loop, which are compiled and connected into an executable cyclic executive program with the GNU tool chain, which is also included with the IDE distribution. The Arduino IDE uses the software to translate the source codes to a text file in hexadecimal that is loaded into the Arduino board by a loader program in the circuitry of the board.

➤ Initial Setup

If the Arduino IDE has been opened, here is what it looks like. It opens in a blank sketch where you can start programming right away. First, we need to customize the board and port settings to enable us to upload code. Connect your Arduino board to your PC with a USB cable.



Fig 4.9 Arduino IDE

4.2.2 Thing Speak

According to the programmers, "Thing Speak is an open access IoT program and API for storing and retrieving data from things over the Internet or a Local Area Network using the HTTP protocol. Thing Speak allows the development of sensor monitoring apps, location tracking applications, and a social network of objects with status updates.

➤ **Features**

- Configure devices to share data through common IoT protocols through Thing Speak
- Real-time display of the sensor data



Fig 4.10 Thing Speak

4.2.3 Rhinoceros 3D

Rhinoceros 3D, also known as Rhino, is one of the most popular 3D modelling software for companies. Rhinoceros 3D is the CAD software which offers a multitude of complex 3D modelling tools to create unimaginable forms, whether from a drawing, a sketch or also a 3D scan, with great accuracy and detail. The software can be designed, drafted, CAMed, prototyped, displayed and illustrated for the majority. It is based on free NURBS modelling. Rhino 6 can be made from curves or mathematical formulae that describe a 3D shape accurately.



Fig 4.11 Rhinoceros 3D

4.3 BLOCK DIAGRAM

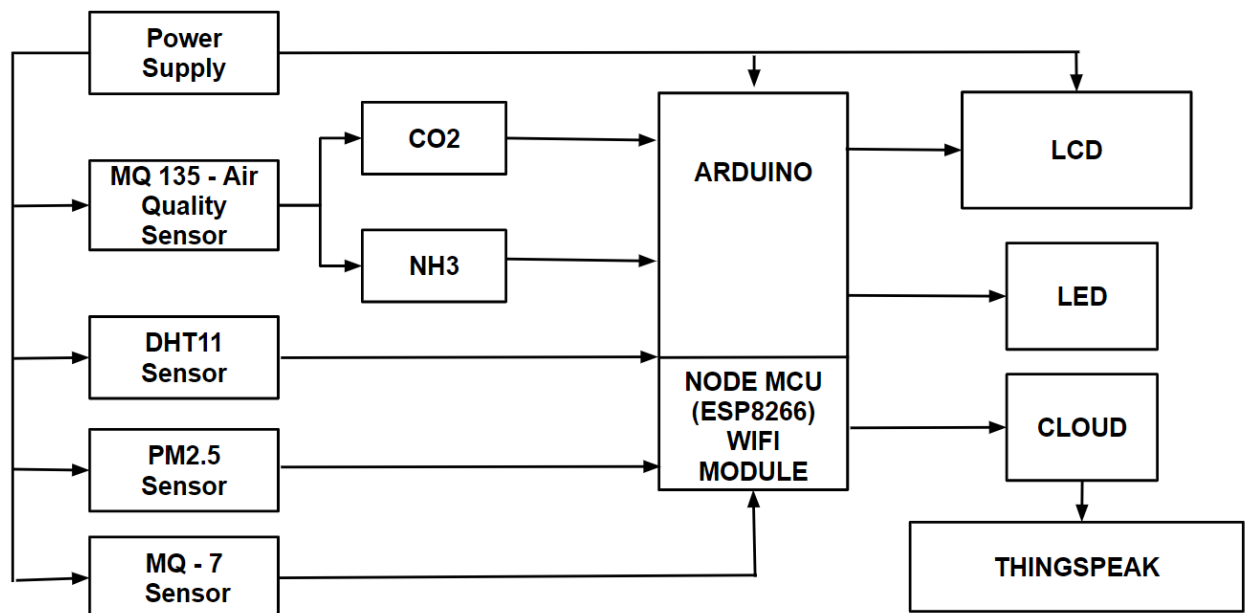


Fig 4.12 Block Diagram

4.4 METHODOLOGY

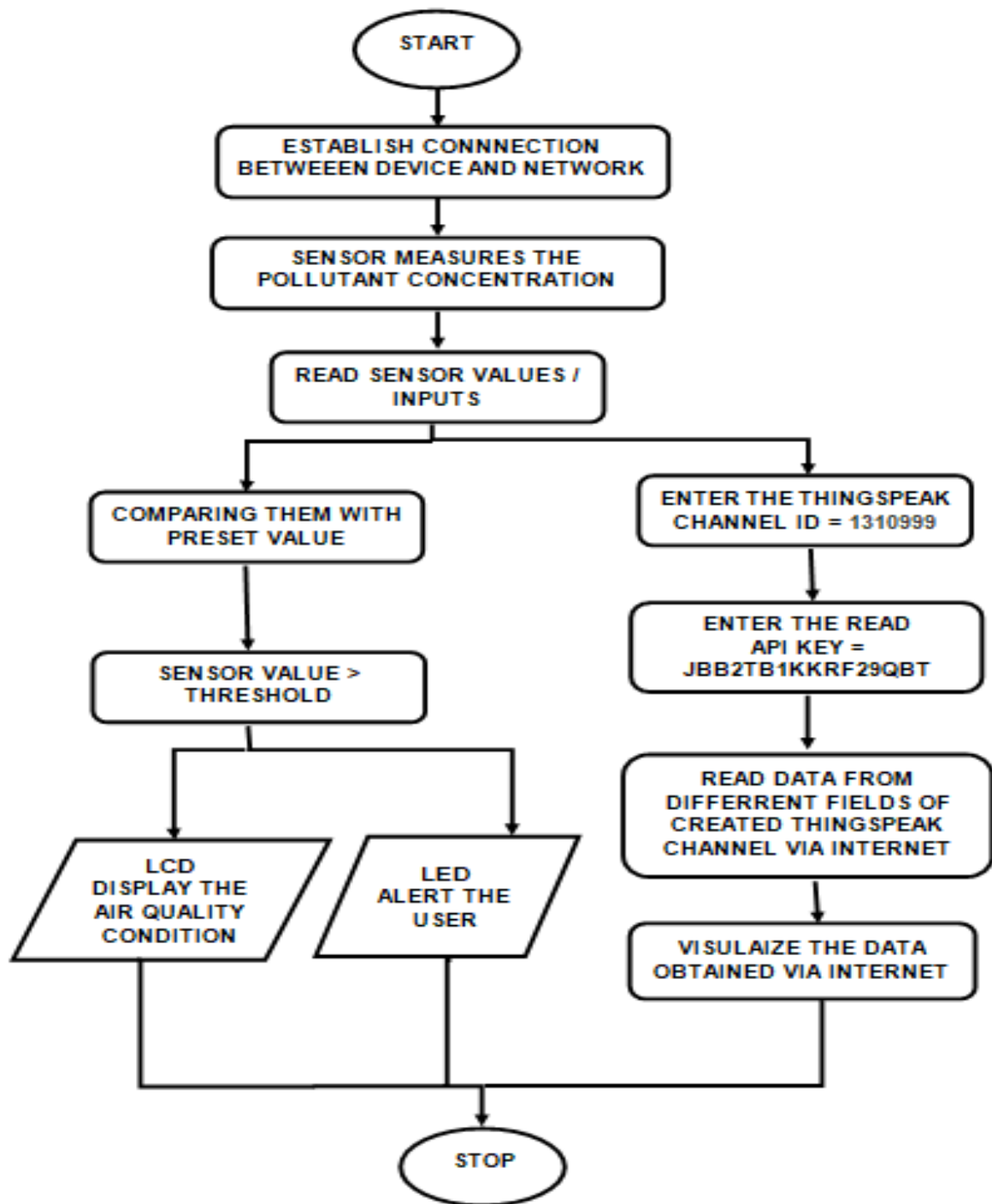


Fig 4.13 Methodology Flow diagram

CHAPTER 5

RESULTS AND DISCUSSION

5.1 RESULTS

The proposed model of design for monitoring indoor air quality was tested in a normal and stimulated environment where we live. Parameters tested included temperature, humidity, amount of PM 2.5, concentration of CO, CO₂ and NH₃. These parameters were monitored for five to six hours per day for a period of 8 days.



Fig 5.1 Proposed Hardware Model

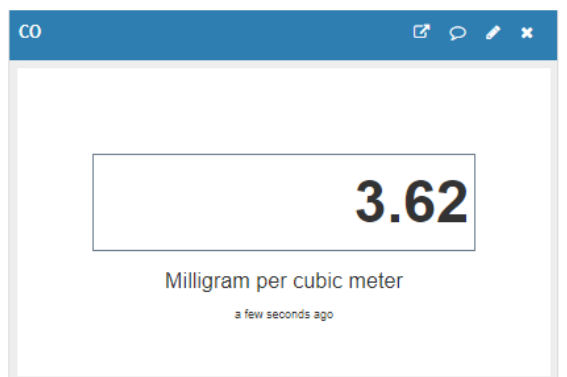
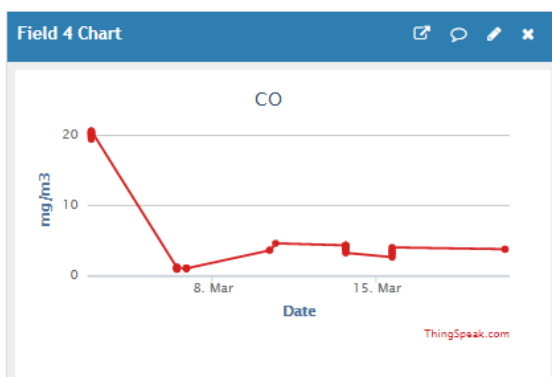
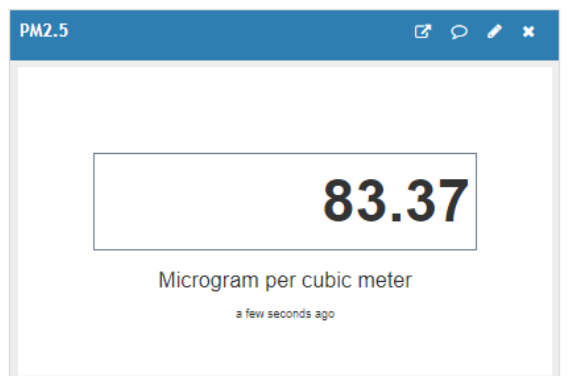
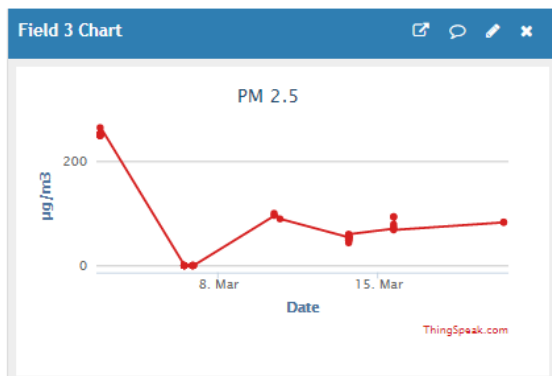
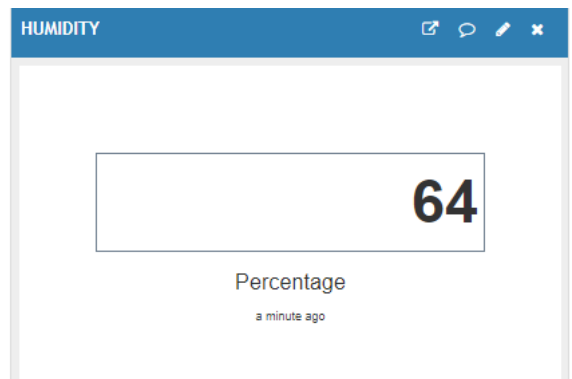
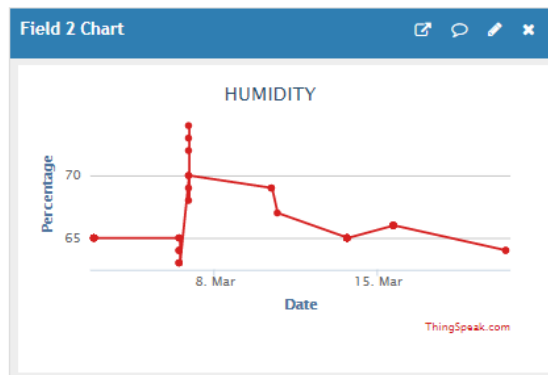
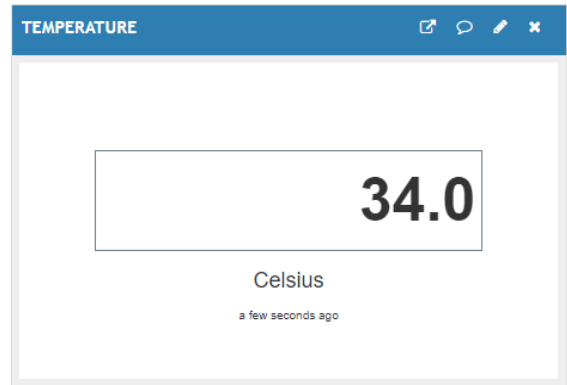
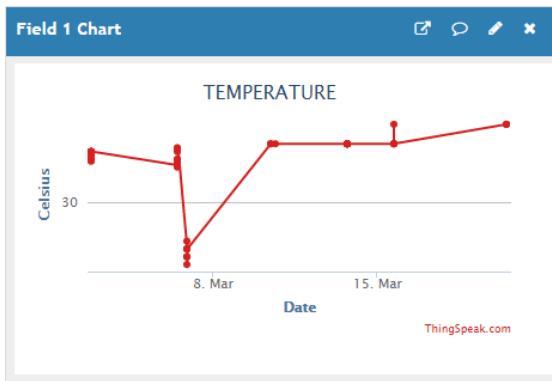
Figure 5.1 shows the complete hardware of the proposed design. The hardware consists of the Arduino board to which the sensors to measure the pollutants and other parameters are connected. An LCD is connected to visualize the immediate output of the sensor. LED's of colours green, white and red are added to quickly notify people about the good, moderate and poor air quality of the surroundings respectively. Data from the Arduino board is sent to Thing speak platform via the Node MCU – ESP8266 module.



Fig 5.2 Sensor Output on LCD

In figure 5.2, the values of the parameters tested in a normal room environment is displayed on the LCD as shown in the table below. The above Fig 12 shows the sample of LCD reading for the project and similar output format holds good for the other parameters such as Temperature, humidity, Heat, rain, Light, air quality and can be viewed on the LCD display.

PARAMETER TESTED	UNIT	OBTAINED OUTPUT
CO2	ppm	326
NH3	ppm	0.2
PM – 2.5	$\mu\text{g}/\text{m}^3$	85.24
CO	mg/m^3	3.62
TEMPERATURE	Celsius	34
HUMIDITY	Percentage	64



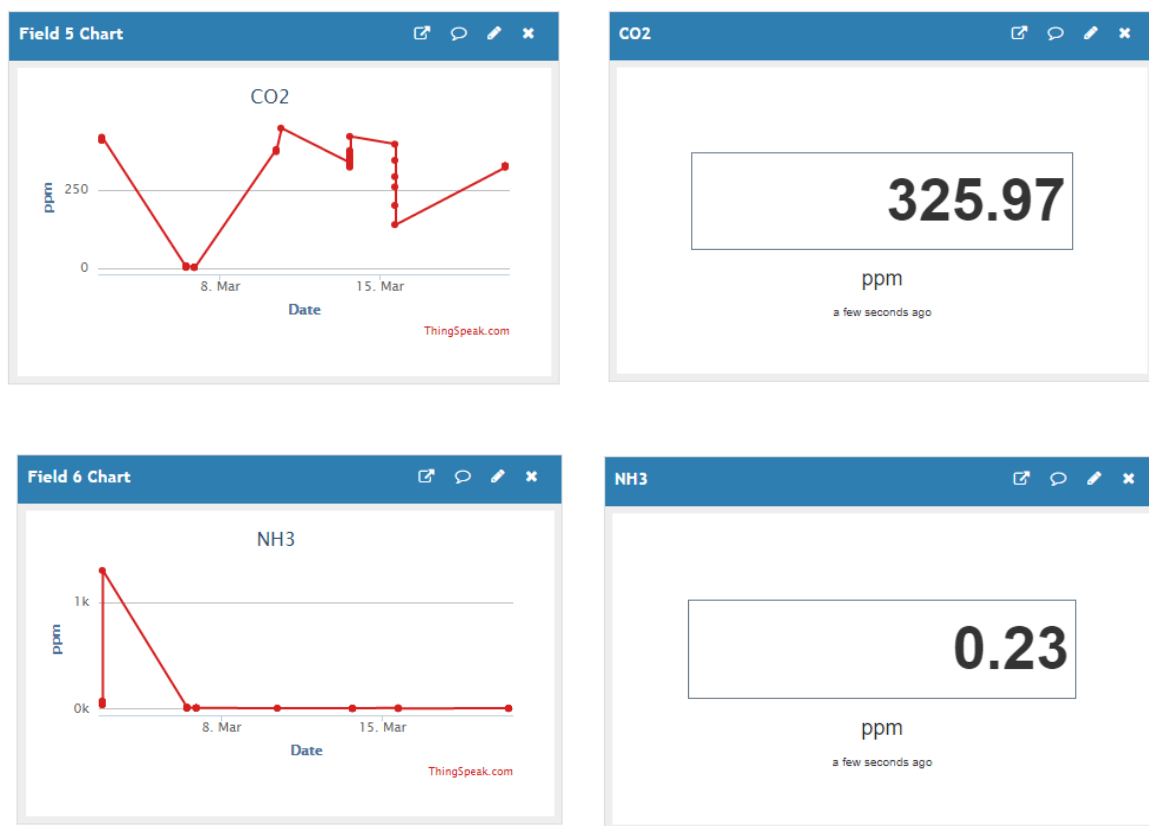


Fig 5.3 Output obtained on Thing Speak

The graphical output at the Thing Speak cloud is seen in Fig 5.3 and can be used only after logging in to the Thing Speak website with the username and password generated, and the cloud provides a stable output.

5.2 DISCUSSION

To measure the conditions of the air of our surrounding we set this category as a base standard of our system.

AQI Category	PM2.5 µg/m3	CO mg/m3	CO2 ppm	NH3 ppm
GOOD	0-60	0-2	400-1000	0-70
MODERATE	61-120	2.1-17	1001-5000	70-300
VERY POOR	>120	>17	>5000	>300

Table 5.1 AQI Base standard of proposed system

DAY	TEMPERATURE	HUMIDITY	PM 2.5	CO	CO2	NH3
1	33	65	83.96	3.19	395.133	0.29
2	34	62	82.77	3.16	392.01	0.21
3	34	65	83.59	3.14	400.1	0.33
4	34	64	84.13	3.19	410.96	0.26
5	33	65	85.49	4.16	370.96	0.26
6	33	60	79.37	3.19	395.15	0.29
7	34	64	84.64	3.26	326.23	0.25
8	35	65	78.52	3.85	370.28	1.20

Table 5.2 Average output readings obtained on 8 different days

Here is the chart of the sensors that was used to take the readings of a certain place on different days. The table shows the average value obtained on each day. From the above table we can observe that CO₂ result is in between 300-1000 ppm. This indicates that there was good flow of air exchange within the indoor space and states that concentrations typical of occupied indoor spaces with good air exchange. It means that CO₂ level, is safe for human health. NH₃ acquired from MQ-135 sensor lies in between 0–70 which is in the range of normal standard value. The chart shows the result of the level of CO is in between 3 to 4.50, which is in moderate range but if anyone stays in this area with prolonged exposure it may cause them minor respiratory risks. Greater exposure of CO above 17 mg/m³ might cause serious health impacts. The optical dust sensor delivers the result within the range 0-90 which implies little to no risk to the humans.

Since CO and PM_{2.5} level lies in the moderate range and the other factors pollutant lies within the normal range, we conclude that the total air quality lies in the moderate range.

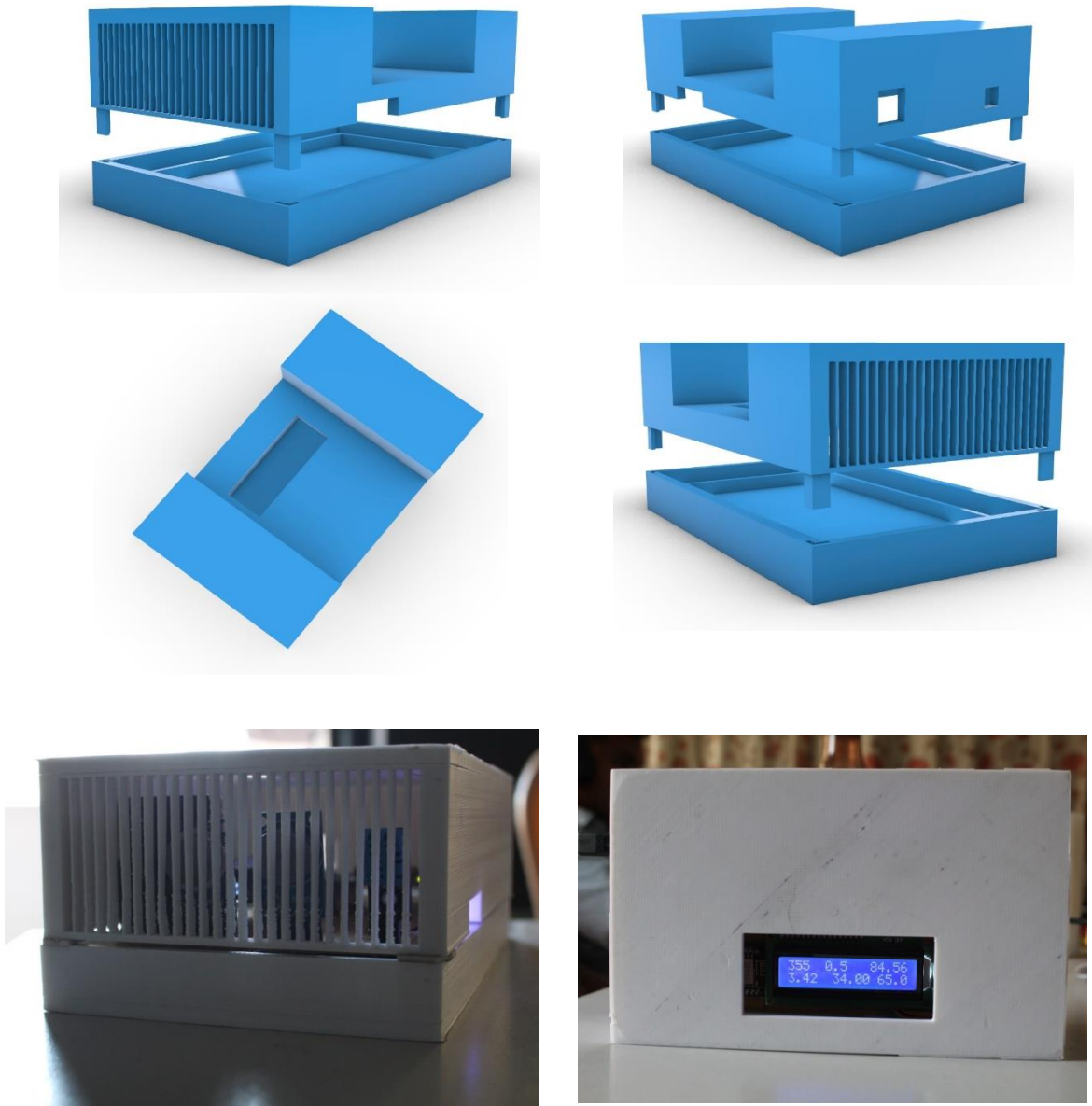


Fig 5.4 Design of 3D printed casing

The above fig 5.4 shows the design of the outer casing of the monitor. The casing is 3d printed with PLA, a biodegradable material. Rhino 3d software was used to design this model. The monitors available in the market are mostly cased of plastic which is harmful to health and hence we used this approach. 3d printed casing can be customized based on our requirements.

CHAPTER 6

SUMMARY AND CONCLUSION

6.1 SUMMARY AND CONCLUSION

The smart way to monitor indoor environment and the quality of air with the help of a low cost and a compact module is presented in our thesis. In the proposed hardware architecture functions of different sensors and their working procedure were discussed. How they work, their functionality, their optimal uses and their data taking procedures and comparison with standard base data's are also analysed here. The sensors measured the concentration of pollutants in the indoor, monitored the pollutant levels on different days and the result was viewed on the LCD. It also sent the sensor parameters to the data server. Our project showed that it is effective, inexpensive and also a reliable one to everybody and the final AQI output will play a crucial role for every individual to take some necessary steps for the betterment of our home and other indoor areas, as it will help to identify the affected surrounding so that we can take early steps to reduce the risk of COPD and other respiratory illness. Thus, COPD can be prevented but cannot be cured completely.

6.2 FUTURE WORK

Our work can demonstrate vast opportunities to work on the device, to develop a user-friendly app and also customize the device based specific indoor environment areas. Additional sensors can be deployed in the device that can measure other pollutants and give a more precise output and alert the user even if a small amount of toxic pollutant is present.

Obtaining the AQI category “good” is difficult in our country due to the vast population but it is not an impossible task. So, the only way to retrieve a toxic free and a safe environment is by installing air purifiers with advanced HEPA filter to purify the air around us which will pave way for a healthy living.

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APPENDICES

PROGRAM USED FOR SENSORS

```
#include <LiquidCrystal.h>

const int rs = 10, en = 11, d4 = 5, d5 = 4, d6 = 3, d7 = 6;
LiquidCrystal lcd(rs, en, d4, d5, d6, d7);

#include "DHT.h"

#define DHTPIN 2    // Digital pin connected to the DHT sensor
int measurePin = A5;
int ledPower = 12;

#define DHTTYPE DHT11 // DHT 11
DHT dht(DHTPIN, DHTTYPE);
#include <MQUnifiedsensor.h>

//Definitionsx
#define placa "Arduino UNO"
#define Voltage_Resolution 5
#define pin A1 //Analog input 0 of your arduino
#define type "MQ-135" //MQ135
#define ADC_Bit_Resolution 10 // For arduino UNO/MEGA/NANO
#define RatioMQ135CleanAir 3.6//RS / R0 = 3.6 ppm
//#define calibration_button 13 //Pin to calibrate your sensor
//Declare Sensor
MQUnifiedsensor MQ135(placa, Voltage_Resolution, ADC_Bit_Resolution, pin,
type);
unsigned int samplingTime = 280;
unsigned int deltaTime = 40;
unsigned int sleepTime = 9680;
float coValue = 0.0;
float airqualityValue = 0.0;
float voMeasured = 0.0;
float calcVoltage = 0.0;
float calcVoltageCO = 0.0;
```

```

float dustDensity = 0.0;
float opticaldustdensity = 0.0;
int R2 = 2000;
float R0 = 7200;
float Rs_gas = 0.0;
float ratio = 0;
float R0135 = 3.12; //Sensor Resistance in fresh air from previous code
float sensor_volt135 = 0.0; //Define variable for sensor voltage
float RS_gas135 = 0.0; //Define variable for sensor resistance
float ratio135 = 0.0; //Define variable for ratio
float h = 0.0;
String airqualityindex = "";
float ppmc02 = 0.0;
float ppmnh3 = 0.0;
int goodpin = 7;
int modpin = 9;
int poorpin = 8;
void setup() {
  Serial.begin(9600); //Init serial port
  pinMode(goodpin, OUTPUT);
  pinMode(modpin, OUTPUT);
  pinMode(poorpin, OUTPUT);
  digitalWrite(goodpin, LOW);
  digitalWrite(modpin, LOW);
  digitalWrite(poorpin, LOW);
  int modpin = 8;
  int poorpin = 9;
  lcd.begin(16, 2);
  lcd.print("AIR QUALITY");
  lcd.setCursor(0, 1);
  lcd.print("      MONITOR");

```

```

delay(3000);
lcd.clear();
lcd.print("  DONE BY ");
lcd.setCursor(0, 1);
lcd.print("CHANDANACAROLINE");
delay(3000);
pinMode(ledPower, OUTPUT);
dht.begin();

MQ135.setRegressionMethod(1); // _PPM = a*ratio^b
MQ135.init();
float calcR0 = 0;
for (int i = 1; i <= 10; i++)
{
    MQ135.update(); // Update data, the arduino will be read the voltage on the
analog pin
    calcR0 += MQ135.calibrate(RatioMQ135CleanAir);
}
MQ135.setR0(calcR0 / 10);
//Serial.println(" done!.");
if (isinf(calcR0)) {
    Serial.println("Warning: Conection issue founded, R0 is infite (Open circuit
detected) please check your wiring and supply");
    while (1);
}
if (calcR0 == 0) {
    Serial.println("Warning: Conection issue founded, R0 is zero (Analog pin with
short circuit to ground) please check your wiring and supply");
    while (1);
}
}
void loop() {

```

```

MQ135.update(); // Update data, the arduino will be read the voltage on the
analog pin
MQ135.setA(110.47); MQ135.setB(-2.862); // Configure the equation values to
get CO2 concentration
ppmcO2 = MQ135.readSensor(); // Sensor will read PPM concentration using the
model and a and b values setted before or in the setup
MQ135.setA(102.2 ); MQ135.setB(-2.473); // Configure the equation values to
get NH3 concentration
ppmnh3 = MQ135.readSensor(); // Sensor will read PPM concentration using the
model and a and b values setted before or in the setup
digitalWrite(ledPower, LOW);
delayMicroseconds(samplingTime);
h = dht.readHumidity();
float t = dht.readTemperature();
voMeasured = analogRead(A0);
delayMicroseconds(deltaTime);
digitalWrite(ledPower, HIGH);
delayMicroseconds(sleepTime);
calcVoltage = voMeasured * (5.0 / 1024);
airqualityValue = analogRead(A5);
float calcVoltageDust = airqualityValue * (5.0 / 1024);
opticalDustDensity = (0.17 *airqualityValue ) - 0.1;
coValue = analogRead(A0);
calcVoltageCO = coValue * (5.0 / 1024);
Rs_gas = (5 - calcVoltageCO) / calcVoltageCO;
ratio = Rs_gas / R0;
float x = 1538.46 * ratio;
float ppmCO = pow(x, -1.709);
float mgCO = Rs_gas * 28.01 * .0409;
int sensorValue = analogRead(A1); //Read analog values of sensor
sensor_volt135 = sensorValue * (5.0 / 1023.0); //Convert analog values to voltage

```

```

RS_gas135 = ((5.0 * 10.0) / sensor_volt135) - 10.0; //Get value of RS in a gas
ratio135 = RS_gas135 / R0135; // Get ratio RS_gas/RS_air
float a = (50 - (10 * ppmc02)) / ppmc02;
float b = a / 76.63;
ppmc02 = (146.15 * (2.868 - b)) + 10;
float c = (50 / (ppmnh3)) - 10;
float d = c / 2.19;
ppmnh3 = 102.694 * pow(d, -2.48818);
lcd.clear();
lcd.setCursor(0, 0);
lcd.print(ppmc02, 0);
lcd.setCursor(5, 0);
lcd.print(ppmnh3, 1);
lcd.setCursor(11, 0);
lcd.print(opticaldustdensity);
lcd.setCursor(0, 1);
lcd.print(mgco);
lcd.setCursor(6, 1);
lcd.print(t, 2);
lcd.setCursor(12, 1);
lcd.print(h, 1);
digitalWrite(goodpin, LOW);
digitalWrite(modpin, LOW);
digitalWrite(poorpin, LOW);
if ((opticaldustdensity > 0 && opticaldustdensity < 60) || (mgco > 0.1 && mgco < 2)
|| (ppmc02 > 400 && ppmc02 < 1000) || (ppmnh3 > 2 && ppmnh3 < 70) )
{
    airqualityindex = "GOOD";
    digitalWrite(goodpin,LOW );
    digitalWrite(modpin,HIGH );
    digitalWrite(poorpin,HIGH );
}

```

```

}
if ((opticaldustdensity > 61 && opticaldustdensity < 120) || (mgco > 2.1 && mgco <
17) || (ppmc02 > 1001 && ppmc02 < 5000) || (ppmnh3 > 71 && ppmnh3 < 300) )
{
    airqualityindex = "MODERATE";
    digitalWrite(modpin,LOW );
    digitalWrite(goodpin,HIGH );
    digitalWrite(poorpin, HIGH);
}
if ((opticaldustdensity > 121) || (mgco > 17) || (ppmc02 > 5000) || (ppmnh3 > 300)
)
{
    airqualityindex = "POOR";
    digitalWrite(poorpin,LOW );
    digitalWrite(goodpin,HIGH );
    digitalWrite(modpin, HIGH);
}
Serial.print("%,");
Serial.print(t);
Serial.print(",");
Serial.print(h);
Serial.print(",");
Serial.print(opticaldustdensity);
Serial.print(",");
Serial.print(mgco);
Serial.print(",");
Serial.print(ppmc02);
Serial.print(",");
Serial.print(ppmnh3);
Serial.print(",");
Serial.print(airqualityindex);

```

```

Serial.println(",END");
delay(3000);
lcd.clear();
lcd.print("AQI : ");
lcd.print(airqualityindex);
delay(1000); //Sampling frequency
}

```

PROGRAM USED FOR THINGSPEAK

```

#include <DHT.h> // Including library for dht
#include <ESP8266WiFi.h>
String apiKey = "39G060B0XE6lZF1V"; // Enter your Write API key from
ThingSpeak
const char *ssid = "SIST-ENC"; // replace with your wifi ssid and wpa2 key
const char *pass = "sist@123";
const char* server = "api.thingspeak.com";
#define DHTPIN 0 //pin where the dht11 is connected
const byte sensor = A0;
const byte addressA = 5; // change the pin as per schematics
const byte addressB = 6; // change the pin as per schematics
const byte addressC = 7;
DHT dht(DHTPIN, DHT11);
WiFiClient client;
int commaposition[] = {
  1,
  1,
  1,
  1,
  1,
  1,
  1,
  1,

```

```

1
};
String format1 = "";
String format2 = "";
String format3 = "";
String format4 = "";
String format5 = "";
String format6 = "";
String coppm = "";
String clockday = "";
String clockmonth = "";
String clockyear = "";
String clockhour = "";
String clockminute = "";
String clockampm = "";
int commapositionint = 0;
int startstring = 0;
int endstring = 1;
int lastStringLength = 0;
void setup()
{
  Serial.begin(9600);
  delay(10);
  dht.begin();
  pinMode(sensor, INPUT);
  Serial.println("Connecting to ");
  Serial.println(ssid);
  WiFi.begin(ssid, pass);
  while (WiFi.status() != WL_CONNECTED)
  {
    delay(2000);

```

```

    Serial.print(".");
}
    Serial.println("");
    Serial.println("WiFi connected");
}
int readSensor (const byte x)
{
    // select correct MUX channel
    if (x == 0)
    {
        digitalWrite (addressA, LOW); // low-order bit
        digitalWrite (addressB, LOW); // high-order bit
    }
    else if (x == 1)
    {
        digitalWrite (addressA, HIGH); // low-order bit
        digitalWrite (addressB, LOW); // high-order bit
    }
    else if (x == 2)
    {
        digitalWrite (addressA, LOW); // low-order bit
        digitalWrite (addressB, HIGH); // high-order bit
    }
    else
    {
        Serial.print ("Invalid Input");
    }
    // now read the sensor
    return analogRead (sensor);
}

```

```

void loop()
{
  while (Serial.available() > 0) {
    delay(500);
    String inBuffer = Serial.readString();
    lastStringLength = inBuffer.length();
    commapositionint = 0;
    //Serial.println(inBuffer);
    startstring = 0;
    endstring = 1;
    for (int i = 0; i < lastStringLength; i++)
    {
      if (inBuffer.substring(startstring, endstring) == ",")
      {
        commaposition[commapositionint] = i;
        Serial.println(commaposition[commapositionint]);
        commapositionint = commapositionint + 1;
      }
      startstring = startstring + 1;
      endstring = endstring + 1;
    }
    format1 = inBuffer.substring(commaposition[0] + 1, commaposition[1]);
    format2 = inBuffer.substring(commaposition[1] + 1, commaposition[2]);
    format3 = inBuffer.substring(commaposition[2] + 1, commaposition[3]);
    format4 = inBuffer.substring(commaposition[3] + 1, commaposition[4]);
    format5 = inBuffer.substring(commaposition[4] + 1, commaposition[5]);
    format6 = inBuffer.substring(commaposition[5] + 1, commaposition[6]);
    startstring = 0;
    endstring = 1;
    // 28.70,51.00,762.31,106,0,13,2,17,13,39, PM,end
    Serial.print(format1);
  }
}

```

```

Serial.print(",");
Serial.print(format2);
Serial.print(",");
Serial.print(format3);
Serial.print(",");
Serial.print(format4);
Serial.print(",");
Serial.print(format5);
Serial.print(",");
Serial.println(format6);
if (client.connect(server, 80)) // "184.106.153.149" or api.thingspeak.com
{

    String postStr = apiKey;
    postStr += "&field1=";
    postStr += format1;
    postStr += "&field2=";
    postStr += format2;
    postStr += "&field3=";
    postStr += format3;
    postStr += "&field4=";
    postStr += format4;
    postStr += "&field5=";
    postStr += format5;
    postStr += "&field6=";
    postStr += format6;
    /*
        postStr += FieldName[i];
        postStr += String(sensorValue);
    */
    postStr += "\r\n\r\n";

```

```

    client.print("POST /update HTTP/1.1\n");
    client.print("Host: api.thingspeak.com\n");
    client.print("Connection: close\n");
    client.print("X-THINGSPEAKAPIKEY: " + apiKey + "\n");
    client.print("Content-Type: application/x-www-form-urlencoded\n");
    client.print("Content-Length: ");
    client.print(postStr.length());
    client.print("\n\n");
    client.print(postStr);

    Serial.println("%s. Send to Thingspeak.", postStr);

}

client.stop();

Serial.println("Waiting...");
}
}

```