INDOOR AIR QUALITY MONITORING SYSTEM

A project report submitted in partial fulfillment of the requirements for the award of the degree of

Bachelor of Technology
in
Computer Science
Submitted by

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This is to certify that this is a bonafide record of the project presented by the students whose names are given below for session 2013-2017 in partial fulfilment of the requirements of the degree of Bachelor of Technology in Computer Science and Engineering.

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ACKNOWLEDGEMENT

I take this opportunity to express my profound gratitude and deep regards to my faculty ARINDAM GHOSH for his exemplary guidance, monitoring and constant encouragement throughout the course of this project. The blessing, help and guidance given by him time to time shall carry me a long way in the journey of life on which I am about to embark.

I am obliged to my project team members for the valuable information provided by them in their respective fields. I am grateful for their cooperation during the period of my assignment.

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Abstract

To build a smart integrated air quality monitoring system with multi-air pollutants sensor network for indoor and outdoor environment. The level of pollution in air can be measured by measuring the pollutants present in the air of that area. The objective of designing a project that monitors air pollution is to prevent the harmful eects of pollutants present in air with the help of a real time monitoring website as well as with android app so that healthy surroundings can be maintained. The website will give the exact location of all the devices placed in a google map and will represent whether the concentration of the pollutants is under the prescribed limit with the help of colours representing dierent AQI levels. Android app will also enhance the same representation by having proles, where user can create prole depending on their health prole and they will get notications and health status depending on the same.

Chapter 1

Introduction

1.1 Pollution

Pollution is defined as the presence of a substance in the environment orchestrating harmful or poisonous effects. Pollution could be broadly classified into two categories, one exists in form of chemical substances and other in form of energy. Pollutants could be naturally occurring or artificially generated. Pollution is also classified into categories such as point source and non-point source.

Point sources : It is a single identifiable source of pollution in air, water, thermal, noise or light.

Non-point sources: It results from many diffused sources, generally from land runoff, precipitation, atmospheric deposition, drainage, seepage, or hydrological modification (rainfall or snowmelt) where tracing the pollution back to a single source is difficult.

1.2 History of Pollution

[**1**] Pollution started from prehistoric times when man created the first fire. According to a 1983 article in the journal Science, "soot" found on ceilings of prehistoric caves provides ample evidence of the high levels of pollution that was associated with inadequate ventilation of open fires. Metal forging appears to be a key turning point in the creation of significant air pollution levels outside the households. Core samples of glaciers in Greenland indicate increases in pollution associated with Greek, Roman and Chinese metal production, but at that time the pollution was comparatively small and could

be handled by nature.

1.3 Types of Pollution

The major forms of pollution are listed below along with particular contaminants relevant to each of them:

1.3.1 Air Pollution

It occurs when harmful substances including particulates and biological molecules are introduced into Earth's atmosphere. Common gaseous pollutants include carbon monoxide, sulphur dioxide, chlorofluorocarbons (CFCs) and nitrogen oxides that are produced as by-products in industry and motor vehicles. Ozone and smog are created as nitrogen oxides and hydrocarbons react to sunlight. Particulate matter, or fine dust is characterized by their micrometre size PM10 to PM1.

Figure 1.1: Air Pollution [**2**]

1.3.2 Water Pollution

It is the contamination of water bodies (e.g. lakes, rivers, oceans, aquifers and groundwater). It is caused by the discharge of wastewater from commercial and industrial waste (intentionally or through spills) into surface waters; discharges of untreated domestic sewage, and chemical contaminants, such as chlorine, from treated sewage; release of waste and contaminants into surface runoff flowing to surface waters (including urban runoff and agricultural runoff, which may contain chemical fertilizers and pesticides); waste disposal and leaching into groundwater; eutrophication and littering.

Figure 1.2: Water Pollution: Tata Steel discharge [**3**]

1.3.3 Soil Pollution

It is a part of land degradation is caused by the presence of XenoBionis (human-made) chemicals or other alteration in the natural soil environment. It is typically caused by industrial activity, agricultural chemicals, or improper disposal of waste, spill or underground leakage. Among the most significant soil contaminants are hydrocarbons, heavy metals, MTBE, herbicides, pesticides and chlorinated hydrocarbons.

Figure 1.3: Soil Pollution Durgapur Coalmine [**4**]

1.3.4 Noise Pollution

Also known as noise disturbance is the disturbing or excessive noise that may harm the activity or balance of human or animal life. The source of most outdoor noise worldwide is mainly caused by machines and transportation systems, motor vehicles engines, aircraft, and trains.

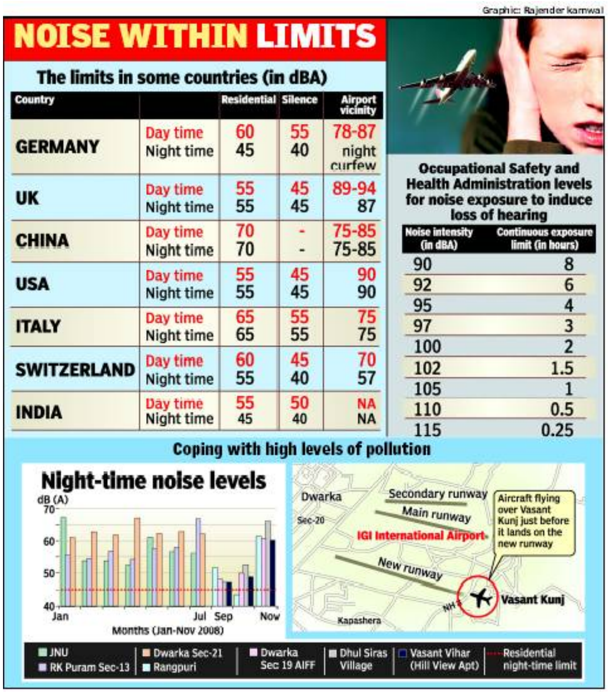


Figure 1.4: Noise Pollution [5]

1.3.5 Radioactive Contamination

It is resulting from 20th century activities in atomic physics, such as nuclear power generation and nuclear weapons research, manufacture and deployment. It is the deposition of, or presence of radioactive substances on surfaces or within solids, liquids or gases (including the human body), where their presence is unintended or undesirable. Such contamination presents a hazard because of the radioactive decay of the contaminants, which emit harmful ionising radiation such as alpha particles or beta particles, gamma rays or neutrons. The degree of hazard is determined by the concentration of the contaminants, the energy of the radiation being emitted, the type of radiation, and the proximity of the contamination to organs of the body.

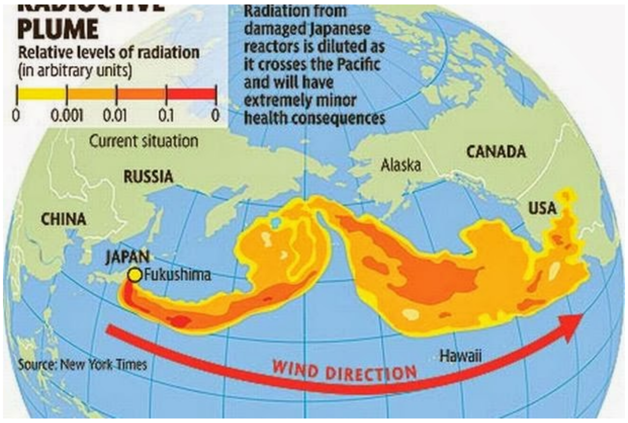


Figure 1.5: radioactive pollution

1.4 Air Pollution

Air pollution is by far the most harmful form of pollution in these times. Air pollution is caused by the harmful gases emitted by cars, buses, trucks, trains, and factories. Gases like sulphur dioxide, carbon mono oxide and nitrogen dioxide are very harmful to the environment causing a lot of damage to humans, animals and the atmosphere. Evidence of increasing air pollution can be anticipated by the galloping rates of lung cancer, asthma, allergies, and various breathing problems along with severe and irreparable damage to flora and fauna. Even the most natural phenomenon of migratory bird has been hampered due to the contaminated air around the world.

1.4.1 Air Pollutants

An air pollutant is a substance suspended in the air that have adverse effects on humans, animals and the ecosystem. The substance can be solid particles, liquid droplets, or gases. A pollutant can be of natural origin or artificially produced. Pollutants are classified as primary or secondary. Primary pollutants are usually produced from a process, such as ash from a volcanic eruption, carbon monoxide gas from motor vehicle exhaust, or the sulphur dioxide released from factories. Secondary pollutants are not emitted directly. Rather, they form in the air when primary pollutants react or interact with other elements or compound in nature. Ground level ozone is a prominent example of a secondary pollutant. Some pollutants may be both primary and secondary: they are both emitted directly and formed from other primary pollutants.

Substances emitted into the atmosphere by human activity includes:

Nitrogen Dioxide

Nature and Sources of the Pollutant: Nitrogen dioxide belongs to a family of highly reactive gas called Nitrogen Oxides (NO_x). These gases are formed when fuel is burned at high temperatures, and come principally from motor vehicle exhaust and stationary sources such as electric utilities and industrial boilers.

Health and Other effects: Nitrogen dioxide can irritate the lungs and lower resistance to the respiratory system of the human body causing infection such as influenza.

Ambient Level: LPA Inc.'s health-based national air quality standard for NO2 is 0.053 ppm

Sulphur Dioxide

Nature and Sources of the Pollutant: Sulphur dioxide belongs to the family of Sulphur dioxide gases (SO_x). These gases are formed when fuel containing Sulphur (mainly coal and oil) is burned, and during metal smelting and also in many other industrial processes.

Health and Other Effects: The major health concerns associated with exposure to high concentrations of SO_2 include effects on breathing, respiratory illness, alterations in pulmonary defences, and aggravation of existing cardiovascular disease. Together, SO_X and NO_X are the major precursors to acid rain, which is associated with the acidification of fresh water lakes and streams, accelerated corrosion of buildings and monuments, and reduced visibility.

Ambient Level: EPA Inc.'s health-based national air quality standard for SO_2 is 0.03 ppm (measured on an annual average) and 0.14 ppm (measured over 24 hours).

Carbon Monoxide

Nature and Sources of the Pollutant: Carbon monoxide is a colourless and odourless poisonous gas formed when carbon in fuels is not burned completely. It is a by-product of motor vehicle exhaust, which contributes more than two-thirds of all CO emissions nationwide.

Health and Other Effects: Carbon monoxide enters the bloodstream and reduces oxygen delivery to the body's organs and tissues. The health threat from CO is most serious for those who suffer from cardiovascular disease. Elevated CO levels is associated with visual impairment, reduced work capacity, reduced manual dexterity, poor learning ability, and difficulty [measured over 8 hours] in performing complex task.

Ambient Level: EPA Inc.'s health based national air quality standard for CO is 9 parts per million (PPM).

Carbon Dioxide

Because of its role as a greenhouse gas it has been described as "the leading pollutant" and "the worst climate pollution". Against this, it is argued that carbon dioxide is a natural component of the atmosphere, essential for plant life and respired out by the human and animal respiratory system. This question of terminology has practical effects, for example as determining whether the U.S. Clean Air Act is deemed to regulate CO_2 emissions. CO_2 currently forms about 405 parts per million (ppm) of earth's atmosphere, compared to about 280 ppm in pre-industrial times, and billions of metric tons of CO_2 are emitted annually by burning of fossil fuels. CO_2 increase in earth's atmosphere has been accelerating.

Particulate matter (PM_{1O}, $PM_{2.5}$ and PM_1)

Nature and Sources of the Pollutants: Particulate matter is the term for solid or liquid particles found in the air. They originate from a variety of mobile and stationary sources (diesel trucks, wood stoves, power plants etc.). Health and Other Effects: Major concerns for human health from exposure to particulate matter are- effects on breathing and respiratory systems, damage to lung tissue, cancer, and premature death. Ambient Level: EPA Inc.'s health-based national air quality standard for PM_{10} is 50 micrograms per cubic meter (measured as an annual average).

1.4.2 Types of Air Pollution

Outdoor Air Pollution: Smog is a type of large-scale outdoor pollution. It is caused by chemical reactions between pollutants derived from different sources, primarily automobile exhaust and industrial emissions. Cities are often centres of these types of activities, and many suffer from the effects of smog, especially during the warm months of the year.

Indoor Air Pollution: Indoor air pollution is the presence of one or more contaminants indoors that carry a certain degree of human health risk. Indoor air issues may be traced to the beginning of civilization. Prehistoric records note the problem of smoke in caves. However, over the last three decades the public has become more aware of indoor air pollution. Various studies show that people spend 65 to 90 percent of their time indoors; 65 percent of that time is spent at home. Field studies of human exposure to air pollutants indicate that indoor air levels of many pollutants may be two to five times, and on occasion more than one hundred times, higher than outdoor levels.

1.4.3 Effects of Air Pollution

Air pollution can affect our health in many ways with both short-term and long-term effects. Different groups of individuals are affected by air pollution in different ways. Some individuals are much more sensitive to pollutants than are others. Young children and elderly people often suffer more from the effects of air pollution. People with health problems such as asthma, heart and lung disease may also suffer more when the air is polluted. The extent to which an individual is harmed by air pollution usually depends on the total exposure to the damaging chemicals, i.e., the duration of exposure and the concentration of the chemicals must be taken into account.

Examples of short-term effects include irritation to the eyes, nose and throat, and upper respiratory infections such as bronchitis and pneumonia. Other symptoms can include headaches, nausea, and allergic reactions. Short-term air pollution can aggravate the medical conditions of individuals with asthma and emphysema. In the great Smog Disaster in London in 1952, four thousand people died in a few days due to the high concentrations of pollution.

Long-term health effects can include chronic respiratory disease, lung cancer, heart disease, and even damage to the brain, nerves, liver, or kidneys. Continual exposure to air pollution affects the lungs of growing children and may aggravate or complicate medical conditions in the elderly. It is estimated that half a million people die prematurely every year in the United States as a result of smoking cigarettes.

1.4.4 Increasing Mortality Rate due to Air Pollution

[7] The World Health Organization estimated in 2014 that every year air pollution causes the premature death of some 7 million people worldwide. India has the highest death rate due to air pollution. India also has more deaths from asthma than any other nation according to the World Health Organization. In December 2013 air pollution was estimated to kill 500,000 people in China each year. There is a positive correlation between pneumonia-related deaths and air pollution from motor vehicle emissions.

Annual premature European deaths caused by air pollution are estimated at 430,000. An important cause of these deaths is nitrogen dioxide and other nitrogen oxides (NO_x) emitted by road vehicles. Across the European Union, air pollution is estimated to reduce life expectancy by almost nine months. Causes of deaths include strokes, heart disease, COPD, lung cancer, and lung infections.

Urban outdoor air pollution is estimated to cause 1.3 million deaths worldwide per year. Children are particularly at risk due to the immaturity of their respiratory organ systems.

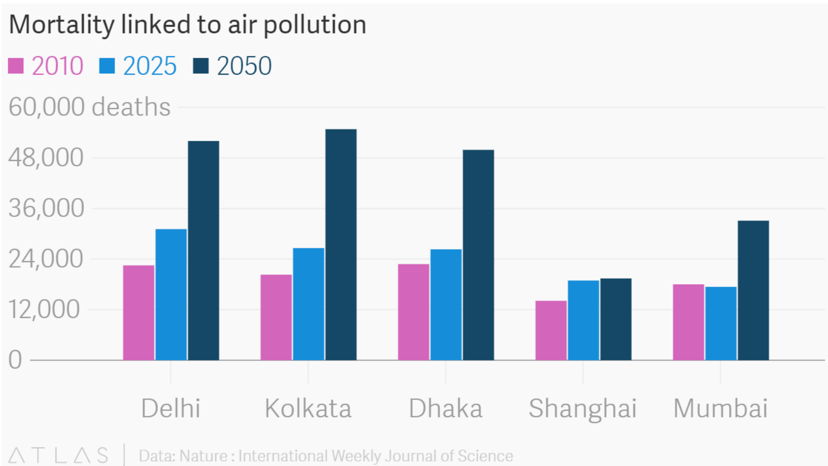


Figure 1.6: Mortality linked to Air Pollution [8]

1.4.5 Major Air Pollution Incidents

[9]

Bhopal Gas Leak

The worlds worst ever industrial accident happened on the night of December 2-3, 1984, when toxic gases leaked from the Union Carbide (now Dow Chemical) pesticide plant in Bhopal, India. The deadly fumes drifted into the sleeping city and people woke with burning eyes and lungs.

Thousands died within days. In the years after, pollutants seeping out of the plant site into groundwater have caused cancer, growth retardation and dizziness, say residents in Bhopal.

Chernobyl Nuclear Accident

The biggest radiation contamination ever happened on April 26, 1986 when the Chernobyl nuclear power plants core went into meltdown, killing 30 people and releasing 100 times more radiation than the atom bombs dropped on Japan. Even more radioactivity remains trapped within the plant.

From 1992 to 2002 in Belarus, Russia and Ukraine more than 4000 cases of thyroid cancer were diagnosed among children and adolescents, mainly due to contaminated milk. The 19-mile exclusion zone around the plant remains uninhabitable.

Gulf of Mexico Oil Spill

On April 20, 2010 the Deepwater Horizon offshore oil rig in the Gulf of Mexico exploded, killing 11 workers and leading to the worst oil spill and environmental catastrophe in US history.

A ruptured underwater pipe spewed almost 5 million barrels of oil into the Gulf over three months, threatening hundreds of miles of beaches, wetlands, and estuaries. Thousands of animals, including turtles, crabs, fish, and birds fell victim, and the local fishing and tourism industries suffered badly.

1.4.6 Air Quality Index

Air quality index (AQI) is a number used by government agencies to communicate to the public how polluted the air currently is or how polluted it is forecast to become. As the AQI increases, an increasingly large percentage of the population is likely to experience increasingly severe adverse health effects. Different countries have their own air quality indices, corresponding to different national air quality standards.

AQI Score	Description	SO_2 (US) µg/m3 24 hr	SO_2 (CHINA) µg/m3 24 hr	O_3 (US) µg/m3 8-hr	O_3 (CHINA) µg/m3 8-hr	NO_2 (US) µg/m3 24 hr	NO_2 (CHINA) µg/m3 24 hr
0-50	Excellent	0	0	0	0	(2)	0
51-100	Good	9.1	50	13	100	(2)	40
101-150	Slightly Polluted	38	150	17	160	(2)	80
151-200	Lightly Polluted	59	475	20	215	(2)	180
201-300	Moderately Polluted	80	800	24	265	122	280
>300	Heavily Polluted	158	1,600	(1)	800	235	565

Figure 1.7: AQI categories and breakpoint concentrations with averaging times [**10**]

The concept of an air quality Index (AQI) that transforms weighted values of individual air pollution related parameters (e.g. $S0_2$, CO, visibility, etc.) into a single number or set of numbers is widely used for air quality communication and decision making in many countries. Thus, An AQI is defined as an overall scheme that transforms weighted values of individual air pollution related parameters ($S0_2$. CO, visibility, etc.) into a single number or set of numbers.

1.5 Indoor pollution and Outdoor pollution comparison

Why is indoor air pollution more hazardous than outdoor air pollution?

According to the EPA, our indoor environment is two to five times more toxic than our outdoor environment, and in some cases, the air measurements indoors have been found to be 100 times more polluted.

The International Agency for Research on Cancer and the World Health Organization have concluded that 80% of all cancers are attributed to environmental rather than genetic factors, including exposure to carcinogenic chemicals, many of which are found in household cleaning products.

The World Health Organization (WHO) agrees, reporting that almost 3% of the global burden of disease is due to indoor air pollution. We spend as much as 90% of our lives indoors nowadays and researchers are investigating our exposure to indoor pollutants as contributing causes to rising incidence of autism, allergies and toxin load.

Why do we need to measure air pollution?

According to a report published earlier this year by the World Health Organisation, air pollution now kills approximately seven million people annually, worldwide. This accounts for as much as one in eight deaths, and is by far the single biggest environmental health risk.

In order to counteract this alarming statistic and take action to clean up air , its important to first understand where the pollution is most concentrated, how it occurs, what elements are involved and how we can neutralise them. In order to do this, comprehensive air monitoring must be undertaken on a national and international scale.

Among other pollutants, air monitors assess the amounts of carbon dioxide (CO_2), carbon monoxide (CO), nitrogen oxides (NO_x), ozone (O_3) and particulate matter 2.5 ($PM_2.5$). This allows us to see where and why pollution occurs, so that we can not only actively avoid overly contaminated areas in our daily routines but also try to implement measures to curb such pollution.

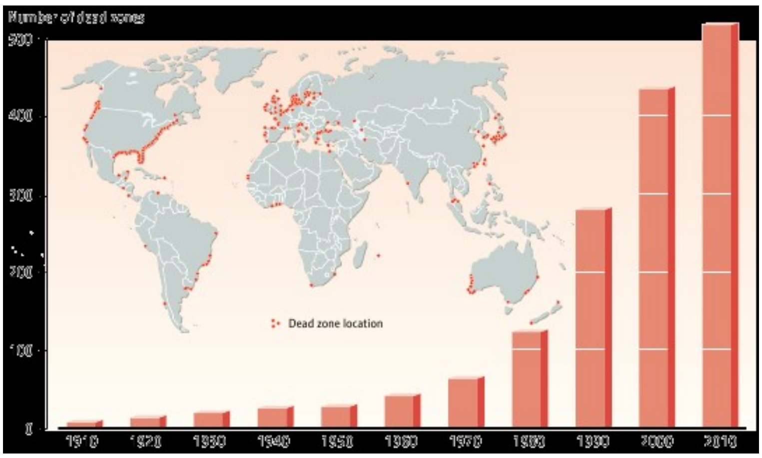


Figure 1.8: AQI levels

1.6 Site Survey

1.6.1 Present Scenario of Air Pollution

[**11**] Greenpeace analysed NASAs satellite data on particulate matter from 2003 to 2015 in India and China, and found that pollution levels in Chino peaked in 2011 and then started to gradually reduce. India, however, saw a spike over the past decade, the last year being the worst on record. The study looked at the aerosol optical depth (A0D), which is h the amount of fine solid particles and liquid droplets in air. The levels in India have increased over the years with north India being the most polluted part of the country. The biggest jump was seen in West Bengal, Bihar, Uttar Pradesh and the National capital Region. The report said that the AOD levels in Indian cities Patna, Kolkata, Delhi, Gorakhpur, Kanpur and Varanasi all went up from 2005 to 2015.

There are large numbers of industries within West Bengal which are emitting harmful gases into the atmosphere and as a matter of fact, this emission is leading to tremendous amount of air pollution in major cities like Kolkata, Asansol, Durgapur and Raniganj. The extent of this pollution is so high, as to raise some serious environmental concerns. Presence of a large number of industries in Durgapur is the single biggest reason for the high level of pollution in this industrial industrial town and the biggest hurdle in the growth of this steel city and the only fact of concern for a healthy living.

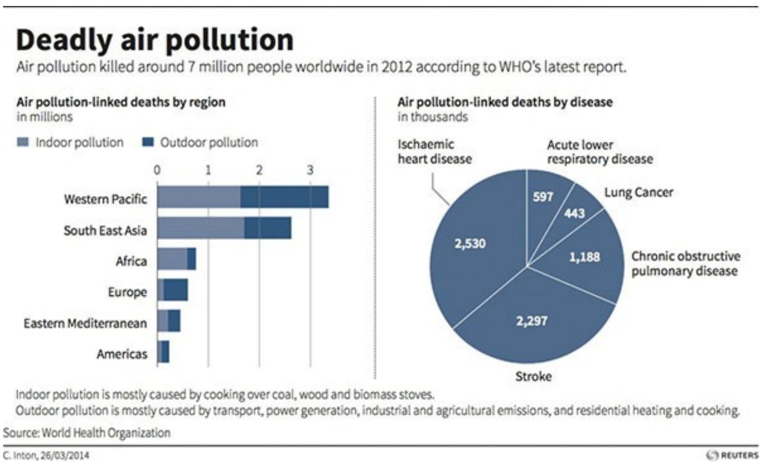


Figure 1.9: AQI levels [**12**]

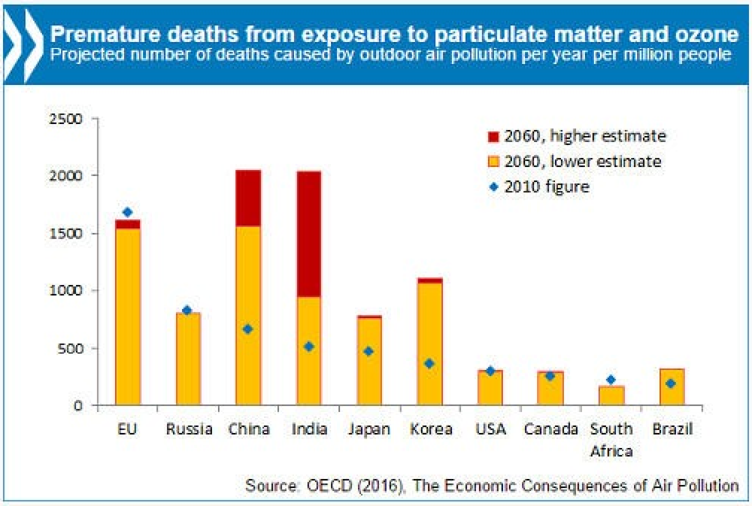


Figure 1.10: AQI levels [**13**]

1.6.2 Status of Air Pollution in Durgapur

With pollution level increasing dangerously in the industrial belts of Haldia and Asansol, the union ministry of environment and forest had imposed a ban in 2010 declaring that no further industries could be set up in these industrial belts, the areas were classified as critically polluted zones. The centre as shortlisted Durgapur as the stage 2 of the smart city mission and the local civic body arranged a public hearing in this connection. The Durgapur Projects Limited (DPL), a state owned power utility, was asked to suspend generation as it continues to release Suspended Particulate Matter (SPM) in the ambient air. In December 2002 the WBPCB had introduced states first ambient air quality monitoring station in Durgapur, which however failed after a couple of years.

NEWS FEED: [**14**]

1. On 12th June 2015 Durgapur steel plant was hit by another mishap.
2. On August 24, the West Bengal Pollution control board registered a police complaint against Durgapur Projects Limited (DPL), a state government undertaking, for violating pollution norms.
3. Durgapur News Services, 26 December 2014: Recent revelation of the fact that pollution linked cancer patients on rise in Asansol-Durgapur.

1.6.3 Major Industries and pollutants emitted by them

Sl.	NAME	PRODUCT	POLLUTANTS
1	Durgapur Steel Plant (D.S.P.)	P.R. TNIT Bars & Rods, Angles, Channels, Wheel & Axle	$S0_2$, NO_x, CO_3, Pb, Ni, As, Cd, Cr, ZnSe, Hg, PM
2	Durgapur Thermal Power Station(D.V.C.)	P.R. Power Generation	$S0_2$, NO_x, Ni, As, Cr, Hg, Acid gases $S0_2$, NO_x, Hg, Acid gases
3	The Durgapur Projects Ltd(D.P.L.)	P.R. Power, Coke, Industrial Gas, Domestic Power, Industrial Power	$S0_2$, NO_x, Ni, As, Cr, Hg, Acid gases
4	NTPC-SAIL Power CO Ltd	P.R. Power Generation & Distribution	$S0_2$, NO_x, Ni, As, Cr, Hg, Acid gases
5	Alloy Steel Plant	P.R. Stainless Steel, Billets etc.	Smoke, Fume, CO, Organic gases, PM, Organic matter
6	Bharat Petroleum Corp. Ltd	P.R. Petroleum Products & Lubricants	CO_2, CO, methanol, soot, benzene, acid rains
7	Birla Corporation Ltd	P.R. Portland Slag Cement	$S0_2$, NO_x, CO, CO_2
8	Durgapur Cements Works	Cements Works	$S0_2$, NO_x, CO, CO_2
9	Durgapur Chemicals Ltd.	P.R. Caustic Soda, Benzene, Bleaching Pow-der, Sodium Chlorophenate, Hydrogen Gas, etc.	$S0_2$, NO_x, Benzene, Organic gases, Cl etc.
10	Graphite India Ltd	Products of Graphite	PM, hydrocarbons, organic matter etc.

Chapter 2

LITERATURE SURVEY

2.1 Air Quality Monitoring

Environment monitoring is crucial and necessary task in enabling healthy living of mankind. Environment monitoring is critical to know whether the quality of our environment is getting better or worse. Information gathered through environment monitoring is important to many decision makers, inside and outside the government. With the results of monitoring, the government can make informed decision about how the environment will affect people and how people are affecting the environment. A lot more work has been done in the area of air quality monitoring system in past years which is summarised below: -

2.1.1 Indoor Air Quality Monitoring

In recent years, indoor air quality (IAQ) has drawn considerable attention in both the public and scientific domains, due to the fact that most buildings appear to fall far short of reasonable air quality goals. Statistics from the U.S. Environmental Protection Agency(EPA) indicate that, on average, the indoor levels of pollutants are two to five times higher than outdoor levels and people in the U.S. spend about 90% of their time indoors. Bad indoor air quality influences human health, safety, productivity, and comfort. IAQ is important and different people have different exposure to pollutants. Providing personalized IAQ information has the potential to increase public awareness of the relationship between their behaviour and air quality; help people to improve their living environments; and also provide valuable information to building managers, policy makers, health professionals, and scientific researchers.

Indoor air quality monitoring is necessary as sometimes we find that indoor level of pollution is higher than outdoor pollution level. This is because of low ventilation and cooking and heating processes. Some of the Indoor Pollution work has been surveyed and their gist is given below.

Pollution Monitoring System using Wireless Sensor Network

In this paper [**15**] they simulated the three air pollutants gases including carbon monoxide, carbon dioxide sulphur dioxide in air. They also apply the approach in various applications like leaking cooking gas in our homes, to alert the workers in oil gas industry to detect the leakage etc. In this they used a sensing unit, a processing unit in the microcontroller, a radio component. The node is designed by integrating the sensor associate circuitry, Atmega 328p low power microcontroller and Xbee communication module. The operating system that runs in the Xbee, coordinates the substances measurement process the acquisition of the change in gas percentages in air and coordinates with the Xbee module for data transmission to the zigbee router. The pollution detector consists array of sensors.

Indoor Air Quality in Homes, Offices & Resturants in Korean Urban AreasIndoor Outdoor Relationship

[**16**] Indoor air quality was monitored and measured pollutants were respirable suspended particulate matter (RSP), carbon monoxide (CO), carbon dioxide (CO_2), nitrogen dioxide (NO_2), and a range of volatile organic compounds (VOCs). In addition, in order to evaluate the effect of smoking on indoor air quality, analyses of parameters associated with environmental tobacco smoke (ETS) were undertaken, which are nicotine, ultraviolet (UVPM), florescence (FPM) and solanesol particulate matter (SolPM). Further both indoor and outdoor air quality were measured and compared and Impact of seasonal differences on both indoor and outdoor air quality were also studied. It was found that indoor pollution in winters was comparatively higher than summer. Indoor Air quality difference due to difference in location were studied and compared. Impact of outdoor pollution on indoor air quality were seen and examined.

Investigation of Indoor Air Quality at Residential Homes in Hong Kong-case Study

[**17**] Air pollutants measured in this study included carbon dioxide (CO_2), respirable suspended particulate matter (PM_{10}), formaldehyde (HCHO), volatile organic compounds (VOCs) and air borne bacteria. During the air measurement, indoor temperature, relative humidity and the age of the building were also recorded. A portable Q-Trak monitor (Model 8551, TSI Inc.) was used to monitor the indoor and outdoor CO_2 concentrations, temperature and relative humidity. The CO_2 analyser equipped with a thermistor and a thin lm capacitive sensor is able to detect CO_2 based on the mechanism of non-disperse infrared detection. A Dust-Trak air monitor (Model 8520, TSI Inc.) was used to measure PM_{10} concentrations.

MAQS: A Personalized Mobile Sensing System for Indoor Air Quality Monitoring.

This paper [**18**] describes MAQS, a personalized mobile sensing system for IAQ monitoring. To improve accuracy and energy efciency, MAQS incorporates three novel techniques: An accurate temporal n-gram augmented Bayesian room localization method that requires few Wi-Fi ngerprints. An air exchange rate based IAQ sensing method, which measures general IAQ using only CO_2 sensors. A zone-based proximity detection method for collaborative sensing, which saves energy and enables data sharing among users.

Detecting Indoor Air Pollutants and taking safety measures

[**19**] A sensor based e-nose is developed to sniff the pollutants presents in indoor environment by [1] to monitor indoor air quality (IAQ) and maintain good IAQ by controlling HVAC system of the room. Also the IAQ monitoring along with the relationship between health and IAQ is discussed but this lacks a proper architecture. The effect of outdoor air and indoor human activity on mass concentration of PM 10, PM 2.5, PM 1 is discussed. It is shown that concentration of carbon dioxide and PM_{10} in domestic kitchen is greater than in living rooms showing that cooking is a major source of pollution. The influence of outdoor air quality on the indoor air quality is discussed. They also tried to provide quantitative information on the levels of potentially important pollutants in three typical environments (homes, offices, and restaurants), to compare indoor and ambient pollution as part of the task of source appointment, and investigate the extent to which certain indoor pollution sources influence the quality of indoor air in urban areas. The above study has confirmed the importance of ambient air quality in

determining the quality of air indoors. Lower detection limits and precisions for the methods used in this study are the limitations of this work.

2.1.2 Outdoor Air Quality Monitoring

As there is increase in urbanisation leading to increased volume of traffic, market places, industries etc. the outdoor air quality is deteriorating day by day. Therefore there is a need of continuous air quality monitoring and using that information in the betterment of general public.

Air Sensing and Alert Generation

[**20**] They simulated the three air pollutants gases including carbon monoxide, carbon dioxide and sulphur dioxide in air. They also apply the approach in various applications like leaking cooking gases in homes, to alert the workers in oil gas industry to detect the leakage etc. In this work they used a sensing unit, a processing unit in the microcontroller, a radio component. The node is designed by integrating the sensor associate circuitry, Atmega 328p low power microcontroller and Xbee, coordinates the substances measurement process the acquisition of the change in gas percentages in air and coordinates with the Xbee module for data transmission to the zigbee router. The pollution detector consist array of sensors. But Dependence Power consumption of sensor nodes need to be minimized and the selection of sensor and material used in construction of the sensor should be selected wisely. Similarly in a microcontroller based toxic gas detecting and alerting system was designing sensed gases like LPG and propane and displayed on LCD. Also an alarm was generated and SMS alert were sent to the authorized person through the GSM when the level of gases exceed certain limit. The system was designed using PIC 16F877 Microcontroller and sensors MQ-2 and MQ-7 for sensing LPG and Propane respectively and displayed on the monitor. When the level of the LPG and Propane exceeds a critical level (LPG greater than 1000 ppm and Propane greater than 10000 ppm), then an alarm is generated and SMS is sent to the authorized user. But here only two gases are detected and lacks the detection of other harmful pollutant which are present in the environment. Although it is an automated system but it requires to reset after every critical situation.

Environment Monitoring and Air Quality Prediction

[**21**] We can use the Air Quality information along with some other useful information to predict the air quality depending upon different criteria. Dif-

ferent methods and modelling techniques can be used to predict air quality of any arbitrary location or time. Following are some literature survey using different useful technologies:-

Using a distance decay regression selection strategy

They reported the first attempt to model NO, NO_2 and NO_x concentration in Los Angeles using a land use regression (LUR) approach. The LUR was developed as part of a study to examine the impacts of outdoor air pollution on respiratory health in children. The LUR method seeks to predict pollution concentrations at a given site based on surrounding land use, road network, traffic, physical environment and population characteristics using a series of buffers. In this work, NO, NO_2 and NO_x concentrations for the LA metropolitan area were modelled using the ADDRESS modelling strategy. The final three prediction models explained 8186 Models. The model provides a relatively easy and feasible way to improve exposure analysis. The influence of slope gradients decreases suggesting that steeper gradient. It concludes that truck routes exerted higher NO_x emissions and had a positive influence on concentration.

Using Machine Learning (semi-supervised learning) in Modelling and Predicting Air Quality

Machine learning and Artificial intelligence is widely used for prediction and classification purpose. Since Air quality depends upon many parameters in a non-linear way hence prediction work in regard to environmental monitoring needs to deal with large volume of data. Therefore, Neural Networks are best suited for this purpose. They use linear chain conditional random field (CRF) and Artificial neural network to infer the real-time and fine-grained air quality information throughout the city, based on the (historical and real-time) air quality data reported by existing monitor stations and a variety of data sources observed in the city, such as meteorology, traffic flow, human mobility, structure of road networks, and point of interests (POIs). It proposes a semi-supervised learning approach based on a co-training framework that consist of two separated classifiers. One is a spatial classifier based on Artificial Neural Network (ANN), which takes spatially-related features as input to model the spatial correlation between air qualities and different locations. The other is a temporal classifier based on a linear-chain conditional random field (CRF), involving temporally-related features to model the temporal dependency of air quality in a location.

The result show the advantage of this method over four categories of baselines, including linear/Gaussian interpolations, classical dispersion models, well-known classification models like decision tree and CRF, and ANN. The city was divided into disjointed grids assuming that air quality in a grid is uniform. Each has a geospatial coordinate and a set of AQI labels to be inferred or already associated if having an air quality monitor station located.

Inferring Air Quality and location by using semi-supervised inference model Based on Urban Big Data Technology

[**22**] It is very complicated question to find out the most optimum location for placing the sensor to cover a large area and predict the air quality of whole area accurately. They tried two answer two questions in their work. First, to infer real-time air quality of any arbitrary location given environmental data and historical air quality data from very sparse monitoring locations. Second, if one needs to establish few new monitoring stations to improve the inference quality, and to determine the best locations for such purpose.

Here they designed a semi-supervised inference model utilizing existing monitoring data together with heterogeneous city dynamics, including meteorology, human mobility, structure of road networks and point of interests (POIs). It also proposes an entropy minimization model to suggest the best locations to establish new monitoring stations. Evaluation of the proposed approach using Beijing air quality data was done. They divided geo-spatial area into disjoint grids, which becomes the basic unit in inference. The AQI values of most grids were completely unknown while the historical AQI values of a small amount of grids can be obtained through existing monitoring stations.

Mobile Environment Monitoring

[**23**] Small Environment Monitoring boxes dynamically moving around the city or given area can be much more efficient and feasible way to cover a large area for air quality monitoring. It can be much more effective method to gather data of more locations which in turn make the prediction process more realistic and accurate. Thus, designing an online GPRS Sensors Array for air pollution monitoring system can be done for this purpose. The system integrates a single chip micro controller, several air pollution sensors, a GPRS modem and a GPS module. The unit can be placed on the top of any moving device such as public transport vehicle. While the vehicle is on the move, the micro controller generates a frame consisting of the acquired air pollu-

tant level from the sensors array and the physical location that is reported from the attached GPS module. The pollutants frame is then uploaded to the General Packet Radio Service Modem (GPRS-modem) and transmitted to the pollution-server for storing the pollutants level of further usage by interested clients such as production agencies, vehicles regeneration authorities, tourist and insurance companies. The pollution server is interfaced to Google maps to display real-time pollutants levels and their locations.

The system software architecture is divided into two layers structure i.e; physical layer and application layer. Physical layer is responsible for acquiring the real time data from the sensor-array and physical location, time and date of the sampled pollutants from the GPS module and is implemented using ANSI C language which is compiled to native microcontroller code. The application layer consist of three primary module: Socket-Server, Air Pollution Index and Google-Mapper. Socket-Server collects and stores data from all the mobile-DAQs. Air Pollution Index calculates pollution categories based on local pollution policies and regulations. But the limitation is that the data collected is limited to the vicinity of six monitoring stations. Also this system monitors only three pollutants that is CO, NO_2 and SO_2.

Comparison of different approaches of Air Quality Prediction

[**24**] A comprehensive comparison between different prediction approaches gives us the idea to select best approach to proceed in a systematic way. In prediction of pollutants PM_{10} and Ozone has been taken into consideration. Here feed forward neural networks (FFNNs), recognized as state-of-the-art approach for statistical prediction of air quality, and are compared with two alternative approaches derived from machine learning: pruned neural networks (PNNs) and lazy learning (LL). All the three approaches are tested in the prediction of ozone and PM_{10} and the predictors are trained. The prediction, issued at 9 a.m. for the current day, show a satisfactory reliability. LL provides the best performances on indicators related to average goodness of the prediction, while PNNs are superior to the other approaches in detecting of the exceedances of alarm and attention thresholds. The better outcome of all the approaches on PM_{10} with respect to ozone can be due to daily average prediction target, which generates a smoother time series than the maximum 8-h moving average adopted for ozone.

A Mobile GPRS-Sensors Array for Air Pollution Monitoring

[**25**] Designing an online GPRS-Sensors Array for air pollution monitoring system can be done. The system integrates a single chip micro controller, several air pollution sensors, a GPRS modem and a GPS module. The unit can be placed on the top of any moving device such as a public transportation vehicle. While the vehicle is on the move, the micro controller generates a frame consisting of the acquired air pollutant level from the sensors array and the physical location that is reported from the attached GPS module. The pollutants frame is then uploaded to the General Packet Radio Service Modem (GPRS-Modem) and transmitted to the Pollution-Server via the public mobile network. A database server is attached to the Pollution-Server for storing the pollutants level for further usage by interested clients such as environment production agencies, vehicles regeneration authorities, tourist and insurance companies. The pollution-Server is interfaced to Google maps to display real-time pollutants levels and their locations. The system software architecture is divided into two layers structure i.e; physical layer and application layer. Physical layer is responsible for acquiring the real- time data from the sensors-array and the physical location, time and date of the sampled pollutants from the GPS module and is implemented using ANSI C language which is compiled to native microcontroller code. The application layer consists of three primary modules: Socket-Server, Air-Pollution-Index, and Google-Mapper. Socket-Server collects and stores pollutant data from all the Mobile-DAQs. Air Pollution-Index calculates pollution categories based on local pollution policies and regulations. Finally, Google-Mapper, makes this pollution information available over the Internet. But the limitations are that the data collected is limited to the vicinity of the six monitoring stations. Also this system monitors only three pollutants that is CO, NO_2 and SO_2.

Inferring Air Quality Based on Urban Big Data

[**26**] They tried to answer two questions in their work. First, to infer real-time air quality of any arbitrary location given environmental data and historical air quality data from very sparse monitoring locations. Second, if one needs to establish few new monitoring stations to improve the inference quality, how to determine the best locations for such purpose? Here they designed a semi-supervised inference model utilizing existing monitoring data together with heterogeneous city dynamics, including meteorology, human mobility, 5 structure of road networks, and point of interests (POIs). It also proposes an entropy minimization model to suggest the best locations to establish

new monitoring stations. Evaluation of the proposed approach using Beijing air quality data was done. They divide geo-spatial area into disjointed grids, which be-comes the basic unit or instance in the inference. Each grid, denoted by r, is a 1km*1km sub-area, with its own geographical coordination. Each grid is associated with an AQI value, of which some need to be inferred. The AQI values of most grids were completely unknown while the historical AQI values of a small amount of grids can be obtained through existing monitoring stations. The meteorology, road network, and POI information of each grid are assumed to be available. The goal was to infer the AQI distribution of any unobserved location v at any given time stamp t(i). The proposed algorithm consists of four stages. In the first stage construction of a spatial-temporal graph, the AQI Affinity Graph (AG) was done to model the spatial-temporal correlation between grids. In the second stage they try to learn the weights of the edges, assuming they represent the correlations between nodes based on their features. The third stage emphasizes on inferring the AQI values for locations. In this stage model presumes those grids whose features were close to each other tend to share similar AQI values. In the final stage the feature weights are adjusted to minimize the uncertainty of the model on inferring the unobserved locations. Finally to recommend the most proper locations in which building new air-quality monitoring stations can lead to the largest accuracy improvement on air quality inference, they proposed entropy-minimization greedy technique which tries to identify a set of nodes that are uncorrelated with the more confident (i.e. low entropy) ones most of the time as the recommended locations for deployment. It is much more effective than myopically minimize entropy or other heuristics. Efficiency of this model could be increased through parallelization.

Air Quality Index(AQI)

[**27**] Awareness of daily levels of air pollution is important to the citizens, especially for those who suffer from illnesses caused by exposure to air pollution. Further, success of a nation to improve air quality depends on the support of its citizens who are well-informed about local and national air pollution problems and about the progress of mitigation efforts. Thus, a simple yet effective communication of air quality is important. The concept of an air quality Index (AQI) that transforms weighted values of individual air pollution related parameters (e.g. SO_2, CO, visibility, etc.) into a single number or set of numbers is widely used for air quality communication and decision making in many countries. Thus, An AQI is defined as an overall scheme that transforms weighted values of individual air pollution related parameters (SO_2, CO, visibility, etc.) into a single number or

set of numbers. After reviewing literature (on AQI), air quality monitoring procedures and protocols, Indian National Air Quality Standards (INAQS), and dose-response relationships of pollutants, an AQI system is devised. The AQI system is based on maximum operator of a function (i.e. selecting the maximum of sub-indices of individual pollutants as an overall AQI). The objective of an AQI is to quickly disseminate air quality information (almost in real-time) that entails the system to account for pollutants which have short-term impacts. Eight parameters (PM_{10}, $PM_{2.5}$, NO_2, SO_2, CO, O_3, NH_3, and Pb) having short-term standards have been considered for near real-time dissemination of AQI. It is recognized that air concentrations of Pb are not known in real-time and cannot contribute to AQI. However, its consideration in AQI calculation of past days will help in scrutinizing the status of this important toxic.

Chapter 3

System Architecure

The Complete System Architecture has been divided into following modules: Sensing Module, Controlling and processing Module, Communication module and Power Module.

3.1 Sensing Module

A sensor is a technological device that detects or senses a signal, physical condition and chemical compounds. It is also defined as any device that converts a signal from one form to another. These are mostly electrical or electronic components. Our Sensing Unit Comprises of Pollutants measuring sensors for different gases. These sensors measures the probable gases found in the environment which are Nitrogen Oxide , Sulphur Dioxide , Carbon Monoxide , Carbon dioxide , and Particulate Matter .

3.1.1 Sensor Description

We have made our environmental monitoring sensors with high quality and Low quality Gas sensors. They are used because to make the device more robust, portable, sensitive, reliable and at the time cheaper too.

Low Quality Sensor

We started our work with Environment Monitoring Box with some low cost sensors which are readily available and are capable of measuring pollutants not very accurately but approximately. They give a indication of increase in pollutant level. They have a larger heating time and are less sensitive. We have used the following Gas sensors: They are semiconductor type gas sensors.

1. Semiconductor type Gas sensor: Semiconductor gas sensors are devices that are made up of heated metal oxides which are used for measurement of gas concentration of a target gas by measuring the electrical resistance of the device.

    - **MQ 135:** MQ 135 sensors are used in air quality control equipments for buildings/offices , are suitable for detecting of NH3,NOx, alcohol, Benzene, smoke,C02, etc. This sensor is composed by micro AL203 ceramic tube, Tin Dioxide (Sn02) sensitive layer, measuring electrode and heater are fixed into a crust made by plastic and stainless steel net. The heater provides necessary work conditions for work of sensitive component. The enveloped MQ-135 has 6 pins,4 of them are used to fetch signals, and other two are used for providing heating current. Resistance value of MQ-135 is difference to various kinds and various concentration gases. When using these components, sensitivity adjustment was made. We calibrated the detector for 100ppm NH3 or 50ppm alcohol concentration in air and use value of Load resistance that is (RL) about 20K (10K to 37K). The proper alarm point for the gas detector was determined after considering the temperature and humidity influence.

    - **MQ7:** MQ7 gas sensor is used to sniff Carbon Monoxide in the atmosphere. It is also composed by micro AL203 ceramic tube, Tin Dioxide (SnO2) sensitive layer, measuring electrode and heater are fixed into a crust made by plastic and stainless steel net. The enveloped MQ-7 has 6 pins, 4 of them are used to fetch signals, and other two are used for providing heating current. Standard measuring circuit of MQ-7, sensitive components consist of 2 parts. One is heating circuit having time control function (the high voltage and the low voltage work circularly). The second is the signal output circuit, it can accurately respond changes of surface resistance of the sensors.

    - **DHT11:** DHT11 Temperature Humidity Sensor features a temperature humidity sensor complex with calibrated digital signal output. By using the exclusive digital-signal-acquisition technique

Figure 3.1: Gas sensors

and temperature humidity sensing technology, it ensures high reliability and excellent long term stability. This sensor includes a resistive type humidity measurement component and an NTC temperature measurement component, and connects to a high performance 8-bit microcontroller, offering excellent quality, fast response, anti-interference ability and cost-effectiveness.

Working Principle (Semiconductor Gas Sensor) : The detection principle of resistive sensors is based on change of the resistance of a thin film upon adsorption of the gas molecules on the surface of semiconductor. The gas-solid interactions affect the resistance of the film because of the density of electronic species in the film. Gas sensor is a subclass of chemical sensors.

Gas sensors measure the concentration of gases in its vicinity. Gas sensor interacts with a gas to measure its concentration. Each gas has a unique breakdown voltage i.e. the (the electric field at which it is ionized. Sensor identifies gas by measuring these voltages. The concentration of the gas can be determined by measuring the current discharge in the device.

Process Flow:

(a) Voltage supply to the sensor.

(b) Ceramic tube made up of Al203 heats up.

(c) Semiconductor chips conductivity is changed due to heating.

(d) Resistance of the circuit changes due to the presence of gas.

(e) Concentration of the gas is calculated by measuring the current since each gas has an unique breakpoint voltage.

2. Optical gas sensors (Dust Sensors) : This type of sensors uses optical absorption/emission scattering of a gas species at defined optical wavelengths. An optical gas sensor consists of a light emitting element, a photo detecting element, a gas sensing element, the gas sensing element responding to light and a filter for picking up fluorescence or phosphorescence. Most optical sensors are usually based on thin films of palladium or chemo chromic oxides coated along the length of an optical fibre. This type of fibre optic sensors are known as optodes. Following methods are used by Optical Sensors

- Ellipsometry (Technique for the investigation of the dielectric properties)
- Spectroscopy (luminescence, phosphorescence, fluorescence, Raman)
- Interferometry (white light Interferometry, modal Interferometry in optical waveguide structures)

In these sensors a desired quantity is determined by:

- Refractive index (speed of light)
- Absorbance
- Fluorescence properties (of the analyse molecules or a chemo-optical transducing element)

GP2Y1010AU0F is a dust sensor by optical sensing system. An infrared emitting diode (IRED) and a phototransistor are diagonally

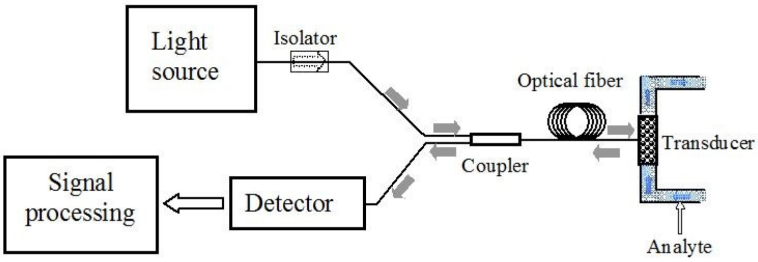


Figure 3.2: Optical sensor

arranged into this device. It detects the reflected light of dust in air. It is effective to detect very fine particle like cigarette smoke.

Working Principle (Optical Sensors):

(a) Dust enters through the hole of the sensors.

(b) Infrared emission take place through the IRED.

(c) Reflection of light through dust particles takes place.

(d) As Photo transistor is diagonally arranged to the IRED it gets activated by the refraction.

(e) The resistance of the Amplifier circuit changes which in turn changes the output voltage.

(f) The concentration of dust is measured by the change in output voltage.

Hight Quality Sensors

These are the sensors which give stable and more accurate reading with less noise. Following are the Sensors that we have used during our project.

1. Multichannel Gas Sensor : Multichannel Gas sensor is an environment detecting sensor with a built in MiCS-6814 which can detect many unhealthy gases, and three gases can be measured simultaneously due to its three channels, so it can help you to monitor the concentration which more than one gas. This sensor belongs to Grove system, and you can plug it onto the Base shield and work with Arduino directly without any jumper wires. The interface of it is I2C, so plug it onto the I2C port of Base shield, then you can start to work it.

   Detectable Gasses:

Figure 3.3: Multichannel gas sensor

- Carbon monoxide CO 1 1000ppm
- Nitrogen dioxide NO_2 0.05 10ppm
- Ethanol C_2H_6OH 10 500ppm
- Hydrogen H_2 1 1000ppm
- Ammonia NH_3 1 500ppm
- Methane CH_4 ¿1000ppm
- Propane C_3H_8 ¿1000ppm
- Iso-butane C_4H_{10} ¿1000ppm

(Mainly we have used this sensor to measure the concentration of CO and NO_2)

2. Grove Temperature & Humidity Sensor (High-Accuracy & Mini) v1.0: This is a multifunctional sensor that gives you temperature and relative humidity information at the same time. It utilizes a TH02 sensor that can meet measurement needs of general purposes. It provides reliable readings when environment humidity condition in between 0-80% RH, and temperature condition in between 0-70C, covering needs in most home and daily applications that dont contain extreme conditions.

3. PM Dust Sensor Module Laser Sensing: $PM_{2.5}$ laser dust sensor is a digital universal particle concentration sensorit can be used to obtain the number of suspended particulate matter in a unit volume of air

Figure 3.4: temperature and Humidity sensor

within 0.3 to 10 microns, namely the concentration of particulate matter, and output with digital interface, also can output quality data of per particle. The sensors can be embedded in a variety of concentrations of environment-related instruments suspended particulate matter in the air to provide timely and accurate concentration data.

Detectable Particulate Matters: Can detect Particulate Matter of Size 1 Micron, 2.5 Micron and 10 Micron.

3.2 Controlling and Processing Unit

A microcontroller is a small and low-cost microcomputer, which is designed to perform the specific tasks of embedded systems like displaying microwaves information, receiving remote signals, etc.

The general microcontroller consists of the processor, the memory (RAM, ROM, EPROM), Serial ports, peripherals (timers, counters), etc.

A microprocessor is a computer processor which incorporates the functions of a computer's central processing unit (CPU) on a single integrated circuit (IC), [1] or at most a few integrated circuits. [2] The microprocessor is a multipurpose, clock driven, register based, digital-integrated circuit which accepts binary data as input, processes it according to instructions stored in its memory, and provides results as output. Microprocessors contain both combinational logic and sequential digital logic. Microprocessors operate on numbers and symbols represented in the binary numeral system.

Difference between Microprocessor & Microcontroller:

Sl.	Microcontroller	Microprocessor
1	It doesnt consist of RAM, ROM, I/O ports. It uses its pins to interface to peripheral devices.	It consists of CPU, RAM, ROM, I/O ports.
2	Microcontrollers are used to execute a single task within an application.	Microprocessors are used for big applications.
3	Its designing and hardware cost is low.	Its designing and hardware cost is high.
4	Easy to replace.	Not so easy to replace.
5	It is built with CMOS technology, which requires less power to operate.	Its power consumption is high because it has to control the entire system.

1. **Arduino Mega 2560**: The Mega 2560 is a microcontroller board based on the ATmega2560. It has 54 digital input/output pins (of which 15 can be used as PWM outputs), 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started.

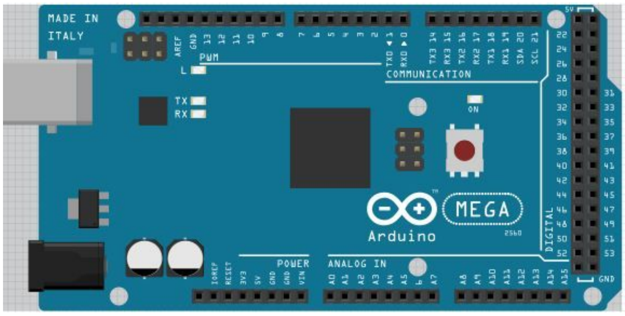


Figure 3.5: Arduino Mega 2560

Sl.	Microcontroller	Microprocessor
1	Operating Voltage	5V
2	Input Voltage (recommended)	7-12V
3	Input Voltage (limit)	6-20V
4	Digital I/O Pins	54 (of which 15 provide PWM output)
5	Analog Input Pins	16
6	DC Current per I/O Pin	20 mA
7	DC Current for 3.3V Pin	50 mA
8	Flash Memory Pin	256 KB of which 8 KB used by bootloader
9	SRAM	8 KB
10	EEPROM	4 KB
11	Clock Speed	16 MHz
12	Length	101.52 mm
13	Width	53.3 mm
14	Weight	37 g

Programming: The Mega 2560 board can be programmed with the Arduino Software (IDE).The ATmega2560 on the Mega 2560 comes pre-programmed with a bootloader that allows you to upload new code to it without the use of an external hardware programmer. It communicates using the original STK500 protocol (reference, C header files).

Warnings: The Mega 2560 has a resettable poly-fuse that protects your computer's USB ports from shorts and overcurrent. Although most computers provide their own internal protection, the fuse provides an extra layer of protection. If more than 500 mA is applied to the USB port, the fuse will automatically break the connection until the short or overload is removed.

Power: The Mega 2560 can be powered via the USB connection or with an external power supply. The power source is selected automatically. External (non-USB) power can come either from an AC-to-DC adapter (wall-wart) or battery. The adapter can be connected by plugging a 2.1mm centre-positive plug into the board's power jack. Leads from a battery can be inserted in the GND and Vin pin headers of the POWER connector.

The board can operate on an external supply of 6 to 20 volts. If supplied with less than 7V, however, the 5V pin may supply less than five volts and the board may become unstable. If using more than 12V, the voltage regulator may overheat and damage the board. The recommended range is 7 to 12 volts.

Memory: The ATmega2560 has 256 KB of flash memory for storing code (of which 8 KB is used for the bootloader), 8 KB of SRAM and 4 KB of EEPROM.

Communication: The Mega 2560 board has a number of facilities for communicating with a computer, another board, or other microcontrollers. The ATmega2560 provides four hardware UARTs for TTL (5V) serial communication. An ATmega16U2 (ATmega 8U2 on the revision 1 and revision 2 boards) on the board channels one of these over USB and provides a virtual com port to software on the computer (Windows machines will need a .inf file, but OSX and Linux machines will recognize the board as a COM port automatically.

The Arduino Software (IDE) includes a serial monitor which allows simple textual data to be sent to and from the board. The RX and TX LEDs on the board will flash when data is being transmitted via the ATmega8U2/ATmega16U2 chip and USB connection to the computer (but not for serial communication on pins 0 and 1).

2. **Raspberry Pi 3 Model B**: A Raspberry Pi is a credit card-sized computer originally designed for education, inspired by the 1981 BBC Micro. Creator Eben Upton's goal was to create a low-cost device that would improve programming skills and hardware understanding at the pre-university level. But thanks to its small size and accessible price, it

Figure 3.6: Raspberry pi

was quickly adopted by tinkerers, makers, and electronics enthusiasts for projects that require more than a basic microcontroller (such as Arduino devices).

The Raspberry Pi is slower than a modern laptop or desktop but is still a complete Linux computer and can provide all the expected abilities that implies, at a low-power consumption level.

The Raspberry Pi is open hardware, with the exception of the primary chip on the Raspberry Pi, the Broadcom SoC (System on a Chip), which runs many of the main components of the boardCPU, graphics, memory, the USB controller, etc. Many of the projects made with a Raspberry Pi are open and well-documented as well and are things you can build and modify yourself.

The Raspberry Pi was designed for the Linux operating system, and many Linux distributions now have a version optimized for the Raspberry Pi. Two of the most popular options are Raspbian, which is based on the Debian operating system, and Pidora, which is based on the Fedora operating system.

Specification:

- **SoC**: Broadcom BCM2837 (roughly 50% faster than the Pi 2)
- **CPU**: 1.2 GHZ quad-core ARM Cortex A53 (ARMv8 Instruction Set)
- **GPU**: Broadcom VideoCore IV @ 400 MHz

Figure 3.7: RTC

- **Memory**: 1 GB LPDDR2-900 SDRAM
- **USB ports**: 4
- **Network**: 10/100 MBPS Ethernet, 802.11n Wireless LAN, Bluetooth 4.0

3. **Additional Component**: We have used our sensors to gather data and microcontroller (Arduino mega 2560) to control the flow of data but we need to get the real time data of a place and also we need to store the data for data analysis.

   RTC (Real Time Clock): A real-time clock (RTC) is a computer clock (most often in the form of an integrated circuit) that keeps track of the current time. To get the time of a data we have connected RTC with the Arduino mega 2560.

   SD Card Module and Micro SD card: SD card module takes the sensor data from the Arduino mega 2560 and store it into the SD card for permanent data storage for further analysis of data.

3.2.1 Prototype Device

3.3 Communication Module

3.3.1 Architecture

The data from the Sensors is received by the Arduino Mega 2560 is transferred to the Raspberry Pi(Microprocessor) via serial Communication (Tx and Rx). Data is stored in the memory of Raspberry Pi for further communication. Raspberry Pi is having Bluetooth and WiFi for communication.

The Raspberry Pi is Connected to the Internet via Wifi. Data from the raspberry pi send to the firebase database using Firebase API. Android application is used to fetch the data stored on cloud . Firebase is real time database , Android application fetch the real time data from cloud using Firebase API.Output display the output on the student screen.

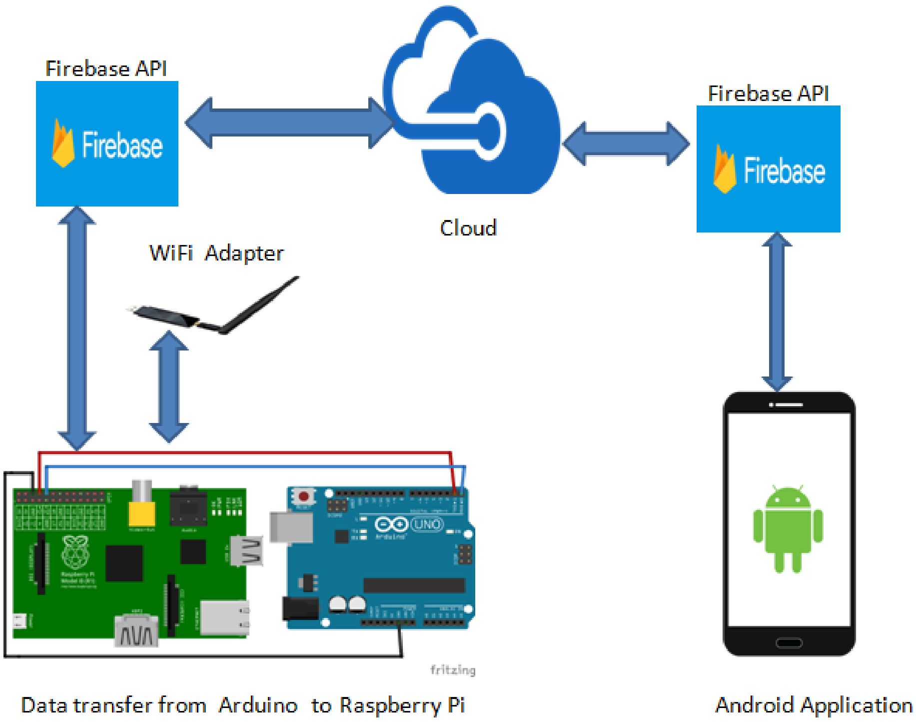


Figure 3.8: Architecture

3.3.2 Working of Android Application

Application needs permission from different hardware, software, internet or any other resource it uses to complete the task. In this application there are four parameter namely Current-Pollution-Status where user can see the current concentration of the pollution of the classroom, Create-Profile where student can create their own profile, view-profile where student can select their profile and compare profile data with the current data of pollutant concentration present in the classroom and Student-Survey in this form student can give their feedback and status of the classroom.

3.4 Power Module

The prototype Box can run on AC main power supply current and is also backed up with a 12 V 12 A Battery for load shedding. The Sensors and Microcontrollers require 5 V DC power supply. So we have designed a circuit that will convert the 220 V AC to 5 V DC for smooth running of the device without any power problem.

Also we have installed a 12 V 12 A dry cell battery for power back up.

Sensors and device power used specification.

Sl.	Sensor	Voltage	Current	Power = V * I
1	Arduino Mega 2560	5V	200mA	1 W
2	Laser dust sensor: SKU:SEN0177	5V	200mA	1 W
3	Temperature and Humidity (TH02)	5V	350 micro-A	1.75 mW
4	Grove - Multichannel gas sensor	5 V	30 mA	150 mW
5	MQ-135	5 V	160 mA	800 mW
6	SD card Module	5 V	100 mA	500mW
7	RTC	5 V	100 mA	500 mW
			Total	3.95 W(approx 4 W)

Formula used:

$$Power = Voltage x Current$$

So we have calculated that our device is drawing approximately 4 W of current.

Calculation of Time taken for batter to discharge:

As we have mentioned that our device is battery enabled for load shedding so we have done a small calculation to find out the duration for the use of batter in case of emergency.

Battery :

$$Voltage = 12V$$
$$Current = 12A$$
$$Power = VoltagexCurrent$$

Using Formula for power Calculation, we calculate the total power of the battery Total power of the Battery =

$$(12x12)W$$

$$Power = 144W$$

Now we calculate the duration for which the Device will run on Battery

$$Time = Batterypower/Devicepower$$
$$= 144W/4W$$
$$= 36Hours$$

So our device will run for approximately 36 hours on battery too.

Chapter 4

Results & Analysis

4.1 Justification of Working of Monitoring Box

The System Architecture proposes a Box fitted with Gas pollutants measuring sensors comprises of (CO2, CO, PM) along with Temperature and Humidity. So we have tried to test that whether our sensors are able to catch the pollutants. So we designed an experiment with the by lighting a matchstick. A match sticks burned for around 15 seconds and we know that It produces gases like (CO2 and CO) during its burning. So we took a matchstick and tested with our made box and we have got some interesting results during the process. The Results are as follows:

Plot (a) shows the variation of CO_2 during the time period (note time axis is 2 data in a second) from (750 to around 780 count) we can see a significance rise in CO_2 pollutants to double of its initial reading (i.e 80 ppm to 150 ppm) during the tenure of matchstick burn.

Also Plot (b) which is the CO variation during the time frame showed a significant variation for the same.

This experiments proves that our box can catch significant variation on pollutants reading and also it is sensitive enough to catch variation over small time frame.

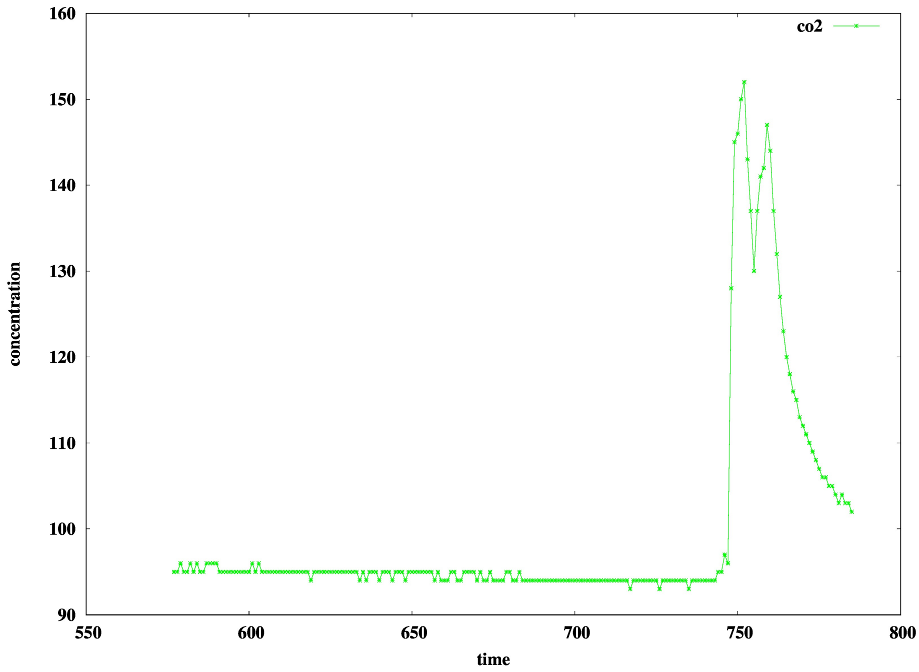


Figure 4.1: CO_2 match testing(plot a)

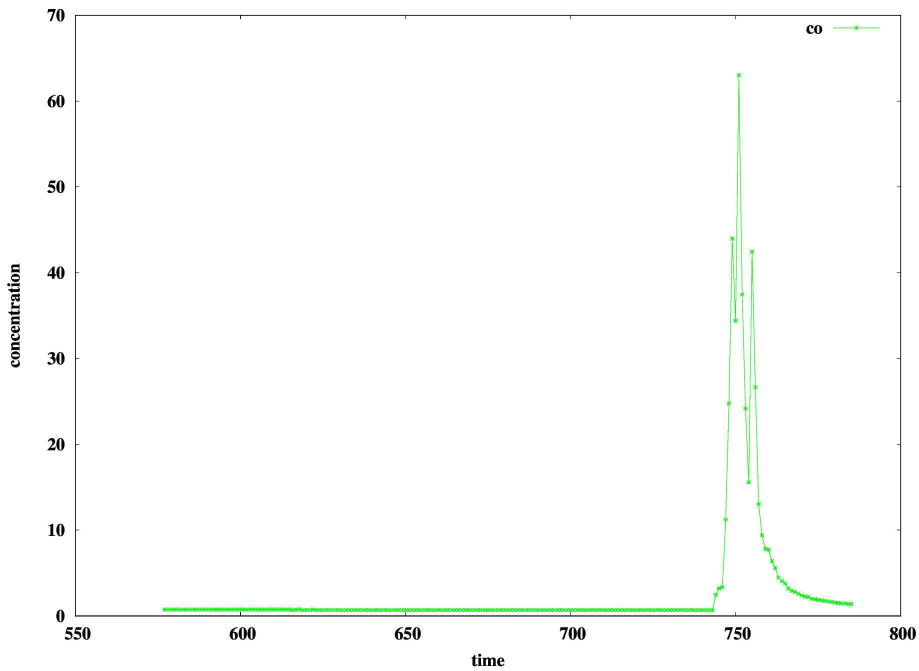


Figure 4.2: CO match testing(plot b)

4.2 Results for the Motivational Survey of our Project

Today the whole world is suffering from the plague of pollution. Whole ecosystem has been affected adversely. Keeping ourselves in home, offices and indoor will not prevent us from getting affected by the contaminated air. To analyse the effects of pollutants in indoor environment, we have done some survey where it is seen that how badly some pollutants are affecting the classroom & laboratory environment.

In the data collected from the students of a class we have studied some features of the classroom environment, (a) ratings of the class environment by students, (b) feel of suffocation in the environment, (c) duration of the class for which the data has been collected

We have done a survey for a classroom of 40 students and we have taken two cases in our survey, (a) feeling of suffocation, and (b) feeling of overall environment of the classroom. Fig. (1a) explains the observations from the data taken from the survey(b), it is seen that environment of the class has got only 10% ratings as poor, whereas it has got 90% ratings as good for a class duration of 1 hour whereas in the same classroom for class duration of 2 hours, 40% of the students rates the environment as poor. At the same time the suffocation has also been surveyed and result shown in Fig. (1b), which reports that, In the class of one-hour suffocation percentage is 25% which is further increase to 62% in the class of two hours. This can be understood easily from the Table 1

From the survey it is clear that the duration of a class is an important feature which infers some information as follow:

- Most of the students feel good in the starting hour of the class.
- Most of the students start feeling suffocated if the class duration is long.
- Most of the students start feeling even more suffocated and irritation if the no. of students is more in the same class duration as mentioned in above point.
- Most of them rated the environment good at less no. of students and worst if the no. of students and duration of the classes increase.

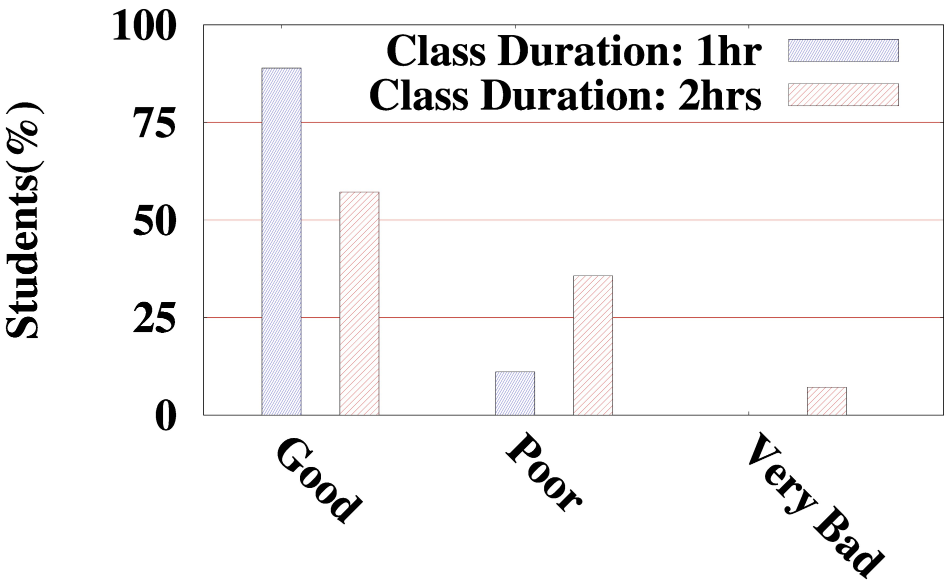


Figure 4.3: Environment of class

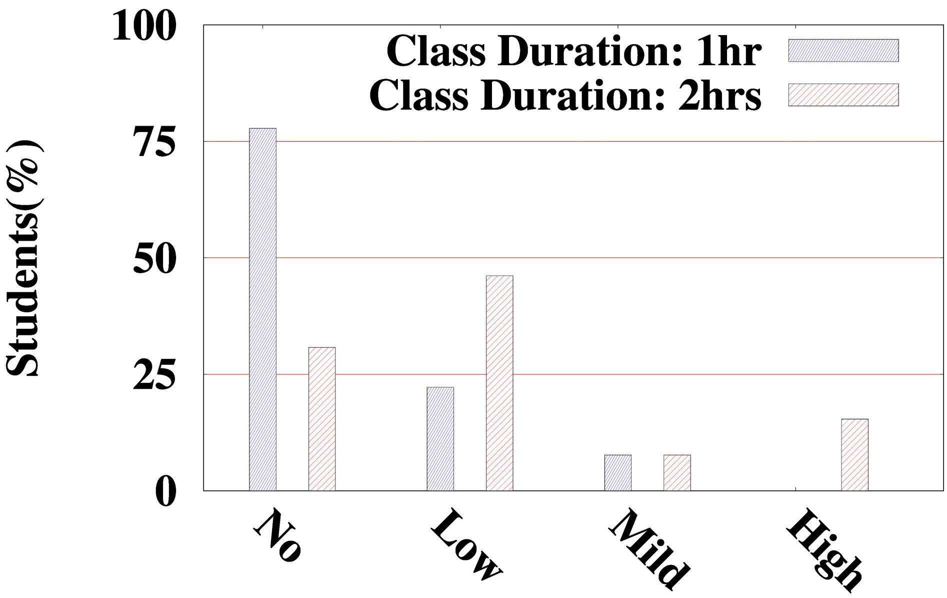


Figure 4.4: feeling of suffocation

4.3 Experimental Setup

After analysing the survey, we needed to find what is going wrong with the classes when the duration was getting longer so we designed an experiment to find out the variation of concentrations like (CO, CO2, PM 2.5, Temperature and Humidity) over time.

The Specifications of our environmental setup are as follows:

1. **Classroom**: The classroom with dimension (8 X 7 X 2.54) m3 having one door with 3 windows and 6 fans as ventilation and air circulation.
2. **Device Placement**: The device was placed 110 cm away from the window at a height of 60 cm.
3. **Class Scenario**: The class was analysed with different strengths of 30, 40 and 60 students. Also Empty classroom data was also taken.

POLLUTANTS	MEAN (EMPTY CLASS)	30 STUDENTS		40 STUDENTS		60 STUDENTS	
		MEAN	CHANGE(%)	MEAN	CHANGE(%)	MEAN	CHANGE(%)
CO_2 (ppm)	199.75	260	28.14↑	310	55.33↑	520	173.00↑
$PM_{2.5}$(μg/m3)	60.34	68.33	13.25↑	73.3	21.48↑	92.79	53.77↑
RELATIVE HUMIDITY(%)	42.95	39.14	8.88↓	38.06	11.38↓	33.73	21.46↓
TEMPERATURE(^{0}C)	31.15	32.2	3.41↑	33.18	6.54↑	33.89	8.79↑

Figure 4.5: Experiment result

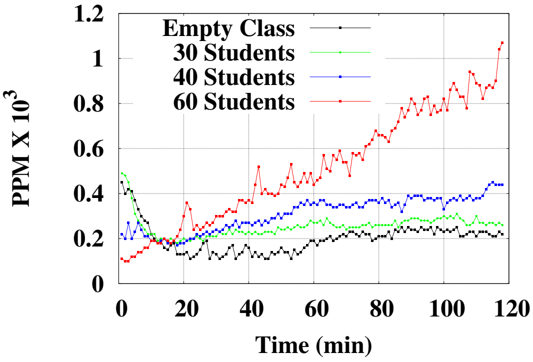
4.4 Experimental Results

The Datasets for pollutants along with temperature and humidity for the classrooms were taken for an interval of about two hours which is the standard duration of our classes. After Analysis of the data we have got significant results and some statistical evidence for justifying the scenario.

Impact of CO_2 During Class: From the Table 2, it is clear that average CO_2 level for the empty classroom is 199.75 ppm which is the normal limit (ASHRAE) [8]. An adult releases appx. 12L of CO_2 in the duration of 1 hr class session. Hence the increase in CO_2 concentration is evident in the scenario with respect to student strength and existing ventilation is inadequate. In the class of 30 students CO_2 value rose 28.14% with respect to the empty classroom and 55.33% for 40 students. When there is 60 students in the room the CO_2 graph is increased with 173% increase compared to empty classroom. Also from Fig. 3 for 60 students it is seen that the graph approaches 1000 ppm (ASHRAE) standard limit [8] and maximum value is 1070 ppm. Thus it can be said that it is not advisable to begin the class with 60 students. However, the class can be continued with 30 and 40 students.

Impact of $PM_{2.5}$ During Class: Average $PM_{2.5}$ level for the empty classroom is 60.34g/m3 and it is varying from 51.25g/m3 to 71.92g/m3 which is in the normal limit (as per EPA 65g/m3 (average)). Also in the class of 30 students the level increased to 13.25% with respect to the empty classroom, when the strength was 40 the level of $PM_{2.5}$ increased to 21.48% with respect to the empty classroom and the average value is 73.29g/m3 and from the plot it is observed that after 100 minutes of class, the level steep up above 100g/m3 which is an alarming limit that the class should be completed within 100-120 minutes of start. But with class strength 60 the $PM_{2.5}$ level is within 67.38g/m3 and 169.57g/m3 with a high increase of 53.77% with respect to empty classroom. Thus the class should not be started with 60 students seeing the high value of $PM_{2.5}$ which is not advisable as per (NAAQS/EPA) standard.

Relative Humidity and Temperature During Class: Relative humidity(RH) and Temperature plots show an interesting characteristic, when there is increase in temperature there is fall in RH of the room. Also, for



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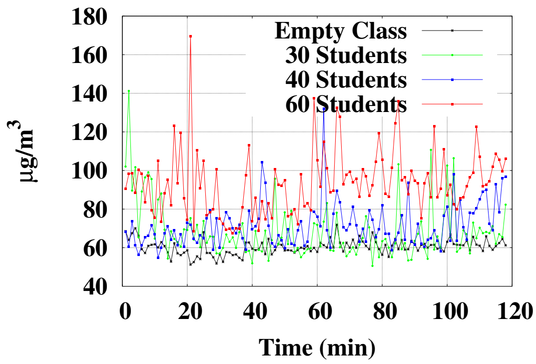

$PM_{2.5}$]

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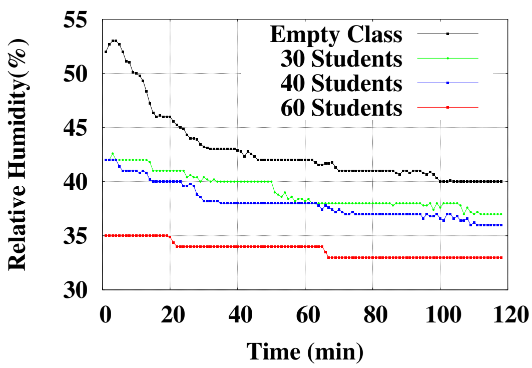

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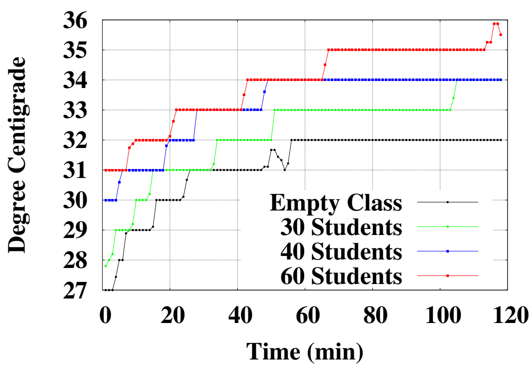

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Figure 4.6: Plots showing variation of different pollution level with time.

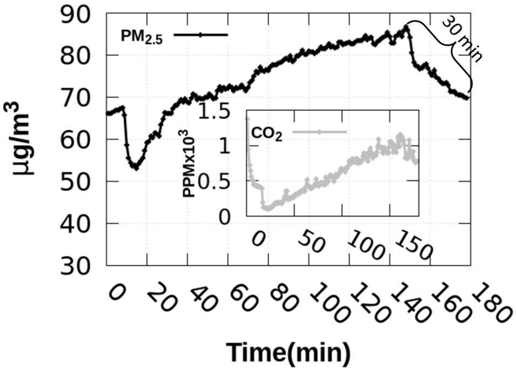


Figure 4.7: Impact of $PM_{2.5}$ and CO_2

the empty classroom, the Humidity is varying from 53% to 40% which is within ASHRAE Standard 65% to 30% [9] and the temperature range is between 270C and 320C. In a class of 30 students the humidity falls by 8.88% and temperature increased by 3.41% with 1.060C rise with respect to empty class. Similarly, for 40 Students humidity fall by 11.38% and there was average 2.030 rise in temperature and within 100 min of class the humidity level was 36% which is just close the lower permissible limit which results in dryness to the students. Interestingly, for 60 Students class the humidity is within 33% and 35% which is very close to the lower permissible limit (30%) with average fall of 21.46% with respect to empty class, resulting in highly discomfort to students and decrease in their performance.

Impact of $PM_{2.5}$ and CO_2 After Class: The level of $PM_{2.5}$ is satisfactory when it ranges from 31-60 and it is moderately polluted in the range of 61-90. The level of $PM_{2.5}$ (after the class is over and the classroom is vacant) is decreasing and after 30 minutes it is dropped from 87 to 70 as shown in Fig. 4, the same effect has been noticed for CO_2 also. During the class hour the pollutants increase rapidly and after the class is over, the concentration of pollutants is decreasing, which can be modelled for getting the duration for which the classroom should leave vacant such that the pollutants settle down to at least satisfactory level and that classroom could be reused.

4.5 Android Application

The Android Application is having functionalities like Viewing the Current Pollutant Status, The student can have their custamized Profile and also the student can give a survey for the Environment of the Classroom.

4.5.1 Current pollution status

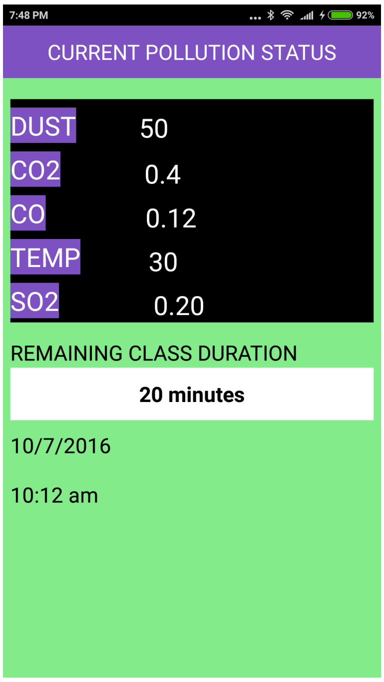
In this activity current concentration of the pollutant of the class is fetched from the device through server. It contains some parameter like Dust concentration, $CO2$, CO , Temperature and $SO2$ along with current date and time of the data

4.5.2 Student profile

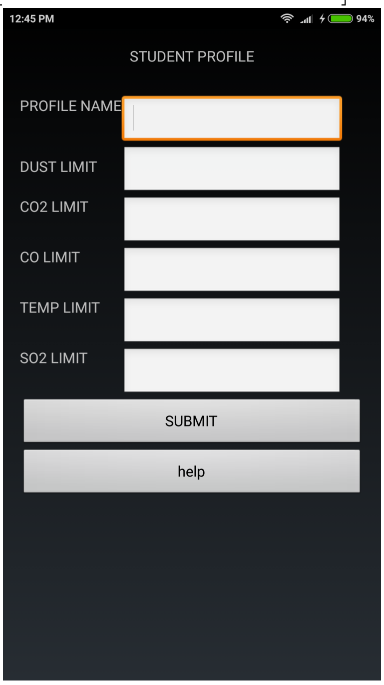
In this activity student can create their own profile based on their health status or prescription prescribed by doctor for some parameter like Dust Limit, CO2 gas Limit, CO gas Limit, Temperature Limit and SO2 gas limit. Current status of classroom pollution is mapped with student profile data. If any value of pollutant present currently in classroom exceeds the student profile data then application generates a notification that this environment is not fit for his/her health. He must leave the classroom as soon as possible.

4.5.3 Student Survey

When students are inside the classroom they can give their feedback about the overall environmental condition of the classroom. Their feedback will be saved in cloud database and administration can look into the matter for further improvement of the issue. Once students completed the feedback procedure, they will receive the confirmation mail on their registered email id.The feedback will be based on student view of the Classroom enviroment conditions.



[Current Pollution Status]



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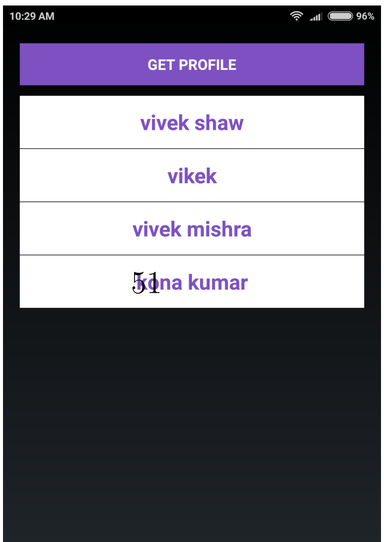

[Student

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