CHAPTER 1

INTRODUCTION

1.1 General

Published data of World Health Organisation (WHO) reveal about 3.7 million deaths from outdoor air pollution in 2012, of which nearly 90% were in developing countries (Associated Press 2014). India is one of the fastest developing countries in the world owing to the economic reforms initiated by the Government of India in 1991. The centres of economic reforms are liberalisation, privatisation and globalisation (Saritha 2014). These have led to the good growth of Indian economy, living standard and life style of people of India rapidly, leading to greater use of private motorised vehicles than public transportation systems, since the latter have not improved at the pace that the private vehicles grown.

Traffic composition in India is of a mixed nature. A wide variety of about a dozen types of both slow and fast moving vehicles exists. Two wheelers and cars (including jeeps) account for more than 80% of the vehicle population in most large cities (Sanjay 2005). The share of buses is negligible in most Indian cities when compared to personalised vehicles whose population share was more than 90% during the year 2000.

The transportation sector is the major contributor to air pollution in urban India. For example, 72% of air pollution in Delhi is caused by vehicular emission. The quantum of emissions generated from motor vehicles in Delhi has seen a big jump from 23% in 1970-71 to 72% in 2000-01 whereas emissions from industrial and domestic sectors together decreased from 77% to
28% in the corresponding years (Sanjay 2005). According to WHO, air pollution caused about one in eight deaths and has now become the single biggest environmental health risk.

1.2 Air Pollution

Air pollution is defined as any atmospheric condition in which certain substances are present in such concentration and duration that they may produce harmful effects on living beings and the environment (Mulaku 2001). Gaseous and particulate substances such as carbon monoxide (CO), sulphur dioxide (SO$_2$), nitrogen dioxide (NO$_2$), ozone (O$_3$) and particulate matter (PM$_{10}$ and PM$_{2.5}$), and lead (Pb) are designated as criteria air pollutants by the United States of Environmental Protection Agency (USEPA) and Central Pollution Control Board (CPCB) in India, as they are primarily responsible for adverse health effects on living being and their properties including vegetation.

Air Pollutants are the substances which, when present in the atmosphere, cause serious health hazards to the flora and fauna, or microbial life; damage materials, or interfere with the enjoyment of life and the use of property (Glynn and Gary 2004).

The atmospheric layer on the surface of the earth (known as troposphere) is a complex dynamic natural gaseous system that is essential for support to life on the planet Earth. The depletion of stratospheric ozone layer due to air pollution has been recognized as a threat to human health as well as to Earth's ecosystems. Indoor air pollution and urban air pollution are listed as two of the World’s worst air pollution problems in the 2008 by Blacksmith Institute’s report on World's Worst Polluted Places (Blacksmith Institute’s report 2008). In this report, air pollution is defined as the introduction of chemicals, particulate matter, or biological materials into the atmosphere that
cause harm or discomfort to humans or other living organisms, or cause
damage to the natural environment or built environment.

Air can be contaminated with pollutants from *anthropogenic activities*
such as industrial and domestic activities and mobile sources. It includes use of
motorised vehicles for transportation, thermal power plants, burning of
municipal solid wastes and road side solid wastes including tyres and other
plastic wastes, construction activities, etc. *Natural sources* such as seasonal
wind and dust storms, volcano eruptions, forest fires, etc. also cause air
pollution occasionally. The major natural and manmade sources of air pollution
and release of specific air pollutants from various sources are depicted in
Figure 1.1.

![Figure 1.1 Picture depicting the natural and manmade sources of Air
Pollution and release of specific Air Pollutants](image)

Threshold limits for air pollutants have been arrived at, in order to
regulate the ambient air quality to which people are normally exposed in their
day to day life. Almost all the countries have prescribed their own ambient air
quality standards. India’s National Ambient Air Quality Standards (NAAQS)
are given in Appendix 1. In the absence of such standards, the pollution data obtained is compared with the Air Quality Index (AQI) (Mahboob and Makshoof 2008). The AQI is a rating scale for outdoor air suggested by the United States Environmental Protection Agency (US EPA) which is presented in the Table 1.1.

Table 1.1 Air Quality Index of Criteria Air Pollutants

<table>
<thead>
<tr>
<th>AQI Category</th>
<th>AQI Rating</th>
<th>PM$_{10}$ (µg/m$^3$)</th>
<th>CO (ppm)</th>
<th>NO$_2$ (ppm)</th>
<th>SO$_2$ (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very good (0-15)</td>
<td>A</td>
<td>0-50</td>
<td>0 – 2.0</td>
<td>0 – 0.02</td>
<td>0 – 0.02</td>
</tr>
<tr>
<td>Good (16-31)</td>
<td>B</td>
<td>51-75</td>
<td>2.1 – 4.0</td>
<td>0.02 – 0.03</td>
<td>0.02 – 0.03</td>
</tr>
<tr>
<td>Moderate (32-49)</td>
<td>C</td>
<td>76-100</td>
<td>4.1 – 6.0</td>
<td>0.03 – 0.04</td>
<td>0.03 – 0.04</td>
</tr>
<tr>
<td>Poor (50-99)</td>
<td>D</td>
<td>101-150</td>
<td>6.1 – 9.0</td>
<td>0.04 – 0.06</td>
<td>0.04 – 0.06</td>
</tr>
<tr>
<td>Very Poor (100 or over)</td>
<td>E</td>
<td>&gt;150</td>
<td>&gt;9.0</td>
<td>&gt;0.06</td>
<td>&gt;0.06</td>
</tr>
</tbody>
</table>

The AQI is calculated by using the following formula.

$$\text{AQI}_{\text{pollutant}} = \frac{\text{pollutant data observed}}{\text{pollutant data standard}} \times 100$$ …………………… 1.1

1.3 Air Quality and Health Effects of Air Pollution

People can live without water for a few days. But, living without breathing air even for a few moments is unimaginable. The air breathed directly gets into bloodstream. Air pollutants have long been a major concern because of the harmful effects that they have on people’s health and the environment. Hence, it is necessary to ensure that air quality is not polluted beyond the threshold limits.

Clean air is a basic requirement of human health. People are exposed to outdoor air pollution by breathing in air pollutants and by exposing eyes and skin while they are outdoors. Exposure is intensified by vigorous activity, as
pollutants are drawn more deeply into the lungs during periods of physical exertion. People who live or work in close proximity to emission sources such as power plants, local industries or highways/major roadways are often exposed to a higher concentration of pollutants for longer periods of time which aggravates their risk of developing acute and/or chronic health problems. Long-term exposure to relatively low levels of pollutants can also cause serious health problems.

The extent of adverse impact due to air pollution depends on many factors, including the concentration of air pollution to which people are exposed, the duration of the exposure, and the potency of the air pollutants. The adverse effects of air pollutants can be minor and reversible (for example, eye irritation due to oxides of nitrogen) or debilitating (for example, aggravation of asthma due to volatile organic compounds) or even fatal (for example, formation of carboxyl-hemoglobin in the blood stream when exposed to carbon monoxide).

The past couple of decades have seen a negative impact of urban traffic growth. Increasing air pollution and traffic noise as a sequel to growing urban traffic has become a common experience. Humans can readily see traffic congestion and can hear traffic noise, but inevitably they are much less aware of odourless, invisible, silent air pollution.

Cities in developing countries often suffer heavily from outdoor air pollution due to extensive use of diesel fuel for transport vehicles and the predominant use of coal for power generation. The proximity of urban population to industrial facilities and the lack of advanced emission controls for vehicles and industry are also responsible for most health risks (Blacksmith Institute’s Report 2009).
Air pollution continues to pose a significant threat to health worldwide. According to The World Health Organization (WHO) assessment of the global burden of disease due to air pollution, the impact of air pollution on health is larger than was assessed only a few years ago. This organisation has estimated that in 2012 around 7 million premature deaths resulted from air pollution, more than double the previous estimates. The new estimate is based on increasing knowledge of air pollution related diseases and use of improved air quality measurements and technology. According to WHO, outdoor air pollution caused 3.7 million premature deaths in 2012 and indoor air pollution is responsible for about 4.3 million premature deaths (UNEP Year Book 2014).

“The risks from air pollution are now far greater than previously thought or understood, particularly for heart disease and strokes,” says Dr Maria Neira, Director of WHO’s Department for Public Health (WHO-PHE 2014).

“Clean air can’t be bought in a bottle, but cities can adopt measures that will clean the air and save the lives of their people.” “Excessive air pollution is often a by-product of unsustainable policies in sectors such as transport, energy, waste management and industry. In many cases, healthier strategies will also be more economical in the long term due to health-care cost savings as well as climate gains,” says Dr Carlos Dora, WHO Coordinator for Public Health, Environmental and Social Determinants of Health (WHO-PHE 2014).

“Cleaning up the air that is being breathed prevents non-communicable diseases as well as reduces disease risks among women and vulnerable groups, including children and the elderly,” says Dr Flavia Bustreo, WHO Assistant Director-General Family, Women and Children’s Health (WHO-PHE 2014).
WHO observes that air quality in many cities worldwide that monitor outdoor (ambient) air pollution fail to meet WHO guidelines for safe levels, putting people to additional risk of respiratory diseases and other health problems. “Too many urban centres today are so enveloped in dirty air that their skylines are invisible,” said Flavia Bustreo, WHO assistant director-general for family, children and women's health (Vivek 2014). Urban centers are growing faster in India, as seen in Appendix 2, within a decade urban areas having population more than a million increased 50% from 34 in 2001 to 51 in 2011.

Key findings from Global Burden of Diseases report 2012 (WHO-Burden of Disease 2012) are as follows;

(i) Increase in death toll: Air pollution is the fifth leading cause of death in India, with 620,000 premature deaths. This is up from 100,000 in 2000 – a six-fold increase.

(ii) Loss in healthy years: Air pollution is the seventh leading cause behind the loss of about 18 million healthy years of life due to illnesses. It comes after indoor air pollution, tobacco smoking, high blood pressure, childhood underweight, low nutritional status, and alcohol use.

(iii) Respiratory and cardiovascular diseases key reasons for air pollution-induced premature deaths: These diseases include stroke (25.48 per cent), chronic obstructive pulmonary disease (17.32 per cent), Ischemic heart disease (48.6 per cent), lower respiratory infections (6.4 per cent), and trachea, bronchus and lung cancer (2.02 per cent).
Major health hazards associated with outdoor air pollution are chronic pulmonary and cardio-vascular stress, lung cancer, asthma exacerbation, acute and chronic bronchitis, restrictions in activity and lost days of work. Infants, children, women and elderly too are more vulnerable to the outdoor air pollution. People with pre-existing health conditions are also significantly affected (Blacksmith Institute’s report 2008 on Health Effects).

Studies indicate that chronic exposure to NO\textsubscript{2} may impair lung development in children and cause structural changes in the lungs of adults. Exposure to ground level ozone (O\textsubscript{3}) causes burning of eyes and irritation of nose and throat, drying out of mucus membranes reducing the ability of body to resist respiratory infections.

The major sources and adverse effects of criteria air pollutants are tabulated in the Table 1.2.
<table>
<thead>
<tr>
<th>Air Pollutant</th>
<th>Sources</th>
<th>Adverse Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Particulate Matter</strong> <em>(PM$_{10}$)</em> and <em>(PM$_{2.5}$)</em>.</td>
<td>Combustion of fossil fuels, factories, construction, demolition, agricultural activities, motor vehicles, and wood burning.</td>
<td>Irritation of respiratory tract, aggravated asthma, and increases the risk of chronic obstructive pulmonary diseases.</td>
</tr>
<tr>
<td><strong>Sulphur dioxide (SO$_2$)</strong></td>
<td>Combustion of sulphur containing fuels.</td>
<td>Irritation of lung tissues, shortness of breath, sore throats, breathing difficulties and can damage overall health and materials.</td>
</tr>
<tr>
<td><strong>Nitrogen oxides</strong> <em>(NO and NO$_2$)</em></td>
<td>Vehicle Exhaust</td>
<td>Reduced visibility and increase the risk of acute and chronic respiratory disease.</td>
</tr>
<tr>
<td><strong>Carbon monoxide</strong> <em>(CO)</em></td>
<td>Incomplete combustion of fuels (largest source - motor vehicles).</td>
<td>High concentration levels lead to headache, dizziness, visual acuity, shrinking mental function, unconsciousness, and death.</td>
</tr>
<tr>
<td><strong>Ozone (O$_3$)</strong></td>
<td>Formed when sunlight causes photochemical reactions involving NO$_X$ and VOCs (emitted from automobiles and industries)</td>
<td>Eye irritation, aggravation of respiratory diseases including reducing lung function, tightness of chest, coughing pain and breathing difficulty and damage to plants and animals.</td>
</tr>
<tr>
<td><strong>Lead (Pb)</strong></td>
<td>Leaded gasoline combustion</td>
<td>Affects blood, kidneys, and nervous, immune system, cardiovascular, and reproductive systems.</td>
</tr>
</tbody>
</table>
The top 10 risk factors for disease in 2010 in Asia (mainly India) are shown in Figure 1.2.

![Top 10 Risk Factors for Disease in 2010 in Asia (mainly India)](http://urbanemissions.blogspot.in/2013_03_01_archive.html)

Figure 1.2 Picture depicting the top 10 risk factors for disease in 2010 in Asia (mainly India)

It is very clear from Figure 1.2 that outdoor air pollution has become India’s fifth highest killer, only after high blood pressure, indoor air pollution, high body mass index and diets that are poor in fruit and vegetables.

The most vulnerable to air pollution are children, the elderly and people already suffering from respiratory or cardiac ailments, says Anumita Roychowdhury, an air pollution expert at the Delhi-based nonprofit Center for Science and Environment (CSE). Even healthy adults in the prime of their lives are at risk. The dangers range from cancer to hypertension, diabetes and birth defects. “We need to be extremely careful,” says Roychowdhury. There are 7,12,000 deaths per year due to air pollution in South Asia including India (Muthukumara 2013).
1.4 Air Pollution related Episodes and Accidents

There were significant incidents of air pollution episodes and accidents happen in the past in different parts of the world. They had drawn very much attention of people towards air pollution and their adverse effects. Thus, it is important to look at those incidents in order to have better idea to take care in the future. They are compiled in the Table 1.3.
<table>
<thead>
<tr>
<th>Place of incident</th>
<th>Year</th>
<th>Duration/ Cause</th>
<th>Adverse Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meuse Valley, Belgium</td>
<td>1930</td>
<td>3 day fog</td>
<td>60 people died</td>
</tr>
<tr>
<td>Manchester, England</td>
<td>1931</td>
<td>9 day fog</td>
<td>592 people died</td>
</tr>
<tr>
<td>Donora, Pennsylvania, USA</td>
<td>1948</td>
<td>4 day fog</td>
<td>7000 people were reported sick and 20 people died</td>
</tr>
<tr>
<td>London, England</td>
<td>1952</td>
<td>4 day fog</td>
<td>4000 deaths (concentrations were several times higher than the current air quality standards)</td>
</tr>
<tr>
<td>Three Mile Island, USA</td>
<td>1979</td>
<td>Nuclide Emissions, within permissible limits. (accidental shutdown of nuclear reactor)</td>
<td>No deaths. The only palpable effect was psychological stress during and shortly after the accident.</td>
</tr>
<tr>
<td>Bhopal, India</td>
<td>1984</td>
<td>4 hours accidental release of methyl isocyanate at a chemical plant</td>
<td>Killed 2800 people by causing Pulmonary edema and Respiratory infections such as bronchitis and bronchial pneumonia and more than 170,000 survivors had adverse health effects and reproductive adverse effects</td>
</tr>
</tbody>
</table>
(Leucorrhea, pelvic inflammatory disease, excessive menstrual bleeding, and suppression of lactation and also stillbirths and spontaneous abortions).

<table>
<thead>
<tr>
<th>Location</th>
<th>Year</th>
<th>Event Description</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chernobyl, Russia</td>
<td>1986</td>
<td>Release of nuclide emissions. (nuclear reactor accident due to improper operation)</td>
<td>32 deaths and 135,000 people and their livestock had to be removed from the region for several months. The radiation exposure could increase the cancer death rates in USSR and Europe in coming years. The agricultural activities near the plant have been halted.</td>
</tr>
<tr>
<td>Fukushima, Japan</td>
<td>2011</td>
<td>Nuclide Emissions. (nuclear reactor accident following a major earthquake)</td>
<td>No deaths or cases of radiation sickness. Over 100,000 people were evacuated from their homes to ensure safety.</td>
</tr>
</tbody>
</table>

1.5 Contributors of Air Pollution in Urban Areas

Transport is the major economic activity that accounts for a bulk of the air pollution in urban areas. Transport and energy sectors are considered to be the major air polluters. Road transport sector causes more urban airborne pollution than any other single human activity (Noman 2002).

Quest for growth (in terms of industry, power generation & transportation) plays a key role in the development process of a country but ultimately deteriorates surrounding environmental conditions. Most of the cities in developed and developing countries have become major “environmental hot spots” that urgently require special attention for studies and proper environmental and transport planning /and traffic management for air pollution and wastes management, ecological sustainability and pollution controls. The man-made causes of air pollution (in %) by various activities in urban centers are shown in the Figure 1.3.

(Source: HaileeZiehr. ‘OBRIEN-envproject, man made vs. natural air pollution.’)

Figure 1.3 Picture showing the contributors of air pollution in percentage in urban areas
1.6 India’s Air Pollution Monitoring System

1.6.1 National Air Quality Monitoring Programme (NAMP)

Central Pollution Control Board (CPCB) of India is a statutory organisation under the Ministry of Environment and Forests (MoEF) established under Water (Prevention and Control of Pollution) Act in 1974. CPCB is also entrusted with relevant powers and functions under the Air (Prevention and Control of Pollution) Act, 1981. It serves as a field formation and also provides technical services to the Ministry of Environment and Forests of the provisions of the Environment (Protection) Act, 1986. It Co-ordinate the activities of the State Pollution Control Boards by providing technical assistance and guidance and resolve disputes among them. It is an apex organization in the country in the field of pollution control, as technical wing of MoEF (CPCB 2014).

CPCB in collaboration with the State Pollution Control Boards (SPCBs) has established a National Ambient Air Quality Monitoring (NAMP) network under the Air (Prevention and Control of pollution) Act, 1981 to collect, compile and disseminate information on air quality. The Ambient air quality is monitored by CPCB, SPCBs, National Environmental Engineering Research Institute (NEERI), Pollution Control Committees, some Universities and Institutes to ascertain the characteristics and concentration of pollutants in the ambient air whether man-made or natural. The data thus generated are transmitted to CPCB for scrutiny, analysis, compilation and publications as a consolidated report.

Monitoring of air pollution helps taking necessary preventive and control measures. CPCB co-ordinates NAMP to ensure uniformity, consistency of air quality data and provides technical and financial support for operating the
monitoring stations. Since large number of personnel and equipment are involved in the sampling, chemical analyses, data reporting etc., it increases the probability of variation and personnel biases reflecting in the data; Hence, it is pertinent to mention that these data be treated as indicative rather than absolute.

As on date, there are 573 operating stations in 240 cities/towns in 26 states and 5 Union Territories of the country. The number of operating stations state-wise and city-wise is given in Appendix 3. Under NAMP, four criteria air pollutants viz., Sulphur Dioxide (SO$_2$), Nitrogen dioxides (NO$_2$), Suspended Particulate Matter (SPM) and Respirable Suspended Particulate Matter (RSPM/PM$_{10}$) have been identified for regular monitoring at all the locations. The monitoring of pollutants is carried out for 24 hours (4-hourly sampling for gaseous pollutants and 8-hourly sampling for particulate matter) with a frequency of twice a week, to have 104 observations in a year (CPCB 2014). The monitoring of meteorological parameters such as wind speed and direction, relative humidity and temperature were also integrated with the monitoring of air quality at few monitoring stations.

1.6.2 Air Quality Monitoring in Chennai under NAMP

There are 11 monitoring stations (10 conventional stations and 1 on-line monitoring station) in Chennai as mentioned in Appendix 3. At all monitoring stations (except the on-line one), samples are collected and tested using analytical procedures which process is very laborious and time consuming. So, this method requires continuous 24 hours sampling using High Volume Sampler and further it is necessary to take samples to laboratory for testing and analysis.

Appendix 3 mentions the disclosure by the Central Pollution Control Board of existence of 11 monitoring stations in Chennai. As per the air
pollution report published by the Tamil Nadu Pollution Control Board in their website (tnpcb.gov.in), 5 monitoring stations have been in operation from the year 2007 to 2013 and 5 proposed sites are under construction and one is an on-line monitoring system at head office, Guindy, Chennai.

1.7 Objectives of the Research

The objectives of this research work are as follows;

- To design and develop a real time mobile monitoring device for air quality measurements using low cost solid state gas sensors (CO, CO₂, NO), Global Positioning System (GPS), Personal Computer and GSM Module.

- To study the air pollution levels in Chennai Metropolitan Area (CMA) using the Air Quality Monitoring Device (AQMD).

- To suggest air pollution prevention and control measures in case of air pollution levels exceeding the norms of CPCB.

1.8 Need for the Research

WHO observed that India ranks among the world’s worst for its polluted air. Out of the 20 most polluted cities in the world, 13 are in India. Sunita Narain, Director General, Centre for Science and Environment (CSE) states: “This database confirms our worst fears about how hazardous air pollution is in our region. Last year, the Global Burden of Disease study pinned outdoor air pollution as the 5th largest killer in India after high blood pressure, indoor air pollution, tobacco smoking, and poor nutrition; about 620,000 early deaths occurred in India from air pollution-related diseases in 2010.”
Sunita Narain also points out that, 18 million years of healthy lives are lost due to illness burden that enhances the economic cost of pollution. Half of these deaths have been caused by ischemic heart disease triggered by exposure to air pollution and the rest due to stroke, chronic obstructive pulmonary disease, lower respiratory track infection and lung cancer.

There are reports published in daily newspapers about the adverse effects of air pollution in Chennai. For example, as per the report published by Janani Sampth on November 20, 2013 in The Times of India titled ‘Chronic respiratory illness cases rise with air pollution,’ Dr G S Vijayachandar (Pulmonologist at the Institute of Thoracic Medicine) reports that 200 of 300 patients suffer from blockages in the airway tract due to air pollution.

As per the report published on August 16, 2014 in the Deccan Chronicle titled “Chennai city pollution affecting kids most,” “Respiratory physicians in the city said that, they are now-a-days seeing more school-going children with complaints of persistent cough and cold. Often misdiagnosed and given antibiotics, these children end up becoming asthmatics.” Further, Physicians say that “they see many parents accompanying kids with recurring episodes of wheezing, breathlessness and coughing. A school kid travels at least six km from home to school and they are exposed to vehicle emission and air pollution.”

As per the report published in The Times of India titled “Chennai breathless as more vehicles add to pollution” on June 2, 2013, the rapid increase in vehicle population in the city has led to ENT and pulmonology clinics seeing a surge in cases of respiratory illnesses caused due to severe air pollution. The allergy and pulmonology clinic at the Madras ENT Research Foundation (MERF), which registered 823 cases of respiratory illnesses in
2011, saw more than 1,472 cases last year with asthma and Chronic Obstructive Pulmonary Disease (COPD) topping the list.

"With its humid weather acting as a trigger, Chennai seems to choke with respiratory issues and the situation will ease only when the pollution levels come down," says, Dr Mohan Kameswaran, Managing Director, MERF (The Times of India 2013). He says 90% of the patients coming to the clinic suffered from dust allergy that stemmed from environmental pollution. "Earlier, only adults had such problems. Now, even children are suffering. Patients who come in with wheezing, nasal bleeding and inflammation where there is a block in the airway, is seen all the result of inhaling soot and carbon particles emitted by vehicles," he says.

At present, scientific understanding of air pollution is not sufficient for accurate prediction of air quality at all times throughout the country. Many more sampling stations are required to cover large areas in cities. The setting up of monitoring stations with conventional equipments for sampling at any location in the urban areas is very costly due to space constraint and exorbitant cost of land. In addition to this, samples have to be taken to laboratories for analytical procedure to find concentrations of pollutants which is laborious and time consuming work although the readings obtained are accurate to the great extent. The recent technology of real time mobile monitoring using solid state gas sensors is compact and cheaper and it helps in monitoring of air pollutants at many places in a short time as compared to conventional stationary monitoring. By using this method, air quality in a large area will be obtained at low cost (Peter et al 2008). The monitored data can be transmitted to Internet in real time for the benefit of public and also to enable the concern authorities to take necessary steps in mitigation of air pollution.
Therefore, real time mobile monitoring can be used for observing pollution levels at many places enhancing the coverage area. It provides regular measurements of air pollutant concentration throughout the city with ease and low cost, which can then be analysed and interpreted. Analysis of monitoring data allows us to assess the impact of air pollution in day to day situations.

At present, CMA has a limited number of six static monitoring stations. The air quality measured at these six locations might not adequately represent true air quality as the CMA has area of about 1189 sq.km. Hence, there is an imperative need for mobile monitoring of air quality in order to cover a large area and the pollution data can be made available in real time for public and decision makers to take necessary steps for control and mitigation measures.

1.9 Thesis Organisation

Chapter 1 of this thesis is the Introduction dealing with the meaning of air pollution, its causes and its adverse affects. The major air pollution related episodes and accidents occurred all over the world are tabulated in chronological order in the Table 1.3. The major contributors of air pollution in urban areas, India’s air pollution monitoring system (NAMP) and that of it at Chennai in particular, objectives and need for the research has been presented.

In chapter 2 the work done in this area has been reviewed including environmental sensors and air quality monitoring devices using these sensors and wireless technology. In the chapter 3, the area under study, about the details of CMA have been described including its demographic details, geography, climate, economy and vehicular growth in general and also recent health problems due to air pollution published in the news papers have been presented at the end of the chapter.
Chapter 4 deals with the design and development of Air Quality Monitoring Device (AQMD) including details about different types of sensors used in the device, GPS module, single chip microcontroller - ARM7 processor, GSM module and software architecture used.

Chapter 5 provides details of air pollution data collection by static monitoring and mobile monitoring carried out using AQMD in the CMA area. Chapter 6 consists of results and discussions on air pollution data that is collected and presented in the chapter 5. In chapter 7, conclusions and suggestions for air pollution prevention and control have been presented.