URBAN AIR QUALITY AND ITS IMPACT ON HUMAN HEALTH: A CASE STUDY OF PUNE CITY

A Thesis submitted in partial fulfillment of the requirement of Master of Technology

in

Environmental Engineering

by

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CERTIFICATE

This is to certify that the dissertation entitled "**URBAN AIR QUALITY AND ITS IMPACT ON HUMAN HEALTH: A CASE STUDY OF PUNE CITY "** is authentic work done by **Mr. RAJ SHAILESH KANAKIYA** Roll.No.**2K13/ENE/02** under my guidance and supervision towards the partial fulfillment of requirement towards the degree of Masters of Technology in *Environmental Engineering* during the academic year 2014 – 2015 in Department of Environmental Engineering of Delhi Technological University.

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ABSTRACT

There has been tremendous Development in Indian cities in last few years Along with that there is downside of development is that more pollutants are been dissipated which causes harm to Air, Water and Land .A Sustainable development the increased number of vehicles , industries have led to enormous amount of pollution load on the Environment. Mapping of Air Quality concentration on GIS platform distinguishing amongst cleaner areas and polluted areas in the city-wide basis is discussed. Spatial Interpolation tool is applied for air pollutant concentration in Pune so quantification of pollutants is been done. Monthly average concentration of different pollutants is displayed and weekdays-weekend concentrations are been displayed on GIS-Map of Pune city. Air Pollutants adversely affects the human heath especially people suffering from respiratory illnesses know precisely this impact on Human Health. Spirometry is performed for the subjects both Asthmatics and Non-Asthmatics and their follow-up is taken for 3 months. A Standard Deviation is for the months of February, March and April is obtained and is compared to Ideal Lung Function for their Weight, Height and Sex. By obtaining the correlation coefficients we infer on that the Particulate Matter concentration affects the lung function results at greatest level. We infer that the Air Quality affect the lung function parameters of Asthmatics more than the Non-Asthmatics. The results of the tests are strong positive correlation between air pollutants of that area for that 3 months and lung functioning of the patients peculiarly for Asthmatics it has correlation is more pronounced with the higher correlation coefficient of FVC are 0.97, 0.90 and 0.89 with respect to $PM_{2.5}$, NO_x and Ozone whereas FVC for Asthmatics is 0.55, 0.34 and 0.42. Aspect of Air Quality is serious and drastic measures taken shall be taken to keep Air Quality under control for the general public health is discussed in this thesis. Atmospheric pollutant levels in an urban street due to high vehicular traffic coupled with urban heat island phenomenon. A study of vehicle exhaust dispersion within different street canyons models in an urban ventilated by cross-wind is conducted at this work to investigate how air pollutant dispersion is exaggerated by wind speed, building height to width ratios, street and building geometries and canyon street number. The most suited Model to given amount of data is Box Model which is used in typical Urban Street in Pune and the levels of concentrations due to contribution of vehicular traffic are found out to be peculiarly high. These models when used in a knowledgeable way we understand the principles that govern the dispersion and transformation of atmospheric pollutants.

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CHAPTER 1

INTRODUCTION

Modern industrialization, Transportation break-through technologies in utilization of fossil-fuel has made our lives comfortable but it has taken a toll on the Natural Environment. Air pollutant is a substance in either form of Solid, Liquid, Gaseous state with present at certain concentration, at certain time, at certain conditions with proves to be harmful for human health and human comfort. It can be classified into main category according to sources. Natural and Manmade. This manmade sources are in this past century have increased drastically which are now proving as a threat to the environment it has increased as a cause of vehicular air pollution, Industrialization. Ill-effects of Air Pollution are that it causes injures human health especially young and the elderly , Affects the growth of trees, plants ,decreases crop yield , damages the surface of buildings , monuments , decreased economic productivity. Visibility is reduced by particles in the air that scatter and absorb light.

1.1 Environmental Pollution in Urban Area

Urban areas are basically the agglomeration of people cramped in one piece of land. Urban cities in India are expanding both laterally and vertically in recent time. The high growth of the cities have led a greater stress on the environment around the city. More population means greater cars on the road and is the vehicular pollution , greater demand of goods means industry been setup around the city contribution to emission .Water pollution intensifies due to increased consumption of water in domestic, public, industrial services. Even solid waste management becomes a great Issue to handle in the cities. The usual solution of the solid waste management problem in Landfills have cause Leachate which affects the quality of Ground-water level. Rapid industrialization and indiscriminate use of chemical fertilizers and pesticides in agriculture are causing heavy and varied pollution in aquatic environment leading to deterioration of water quality and depletion of aquatic biota.[1]

Due to the different soils and presence of indigenous rocks, the groundwater contains a variety of dissolved ions in different concentrations. The concentration of the dissolved ions determines the suitability of water for different purposes.[2]

The rapid urbanization and industrialization consequential in expansion of the settlements of Pune. Cooking from solid fuels use of raw materials like kerosene, wood, peat coal in low income groups, Smoking, Burning firewood for heat , Use of Hair-spray, Refrigerants contributes to air pollution. Due to increase in personal vehicles and less dependency on public transport, Cities are facing major problems of congestion and air pollution.

The total numbers of on-road vehicles in and the use of liquid fuels like petrol and diesel can only make the situation worse. Each category Motorcycles, cars , light duty vehicles, Heavy Duty Vehicles, Buses with different emissivity is contributes to Air Pollution. Approximately 30000 small-scale industries are there in Pune district.

The major types of industries are paper and wood, foundry, metal, forging, automobile, engineering, textile, dairy, steel mills, Steel galvanising units. Domestic & Commercial though, cleaner fuel like LPG has taken over in urban areas, but people living in slums continue to use polluting fuels like firewood, biomass, etc. With ever-rising population, the emissions from domestic sectors are always increasing. India still utilizes it 80% of electricity from thermal power plant that is burning of coal cause severe negative impact on the environment this introduces the pollutants such as Sulphur di oxide, Nitrogen di oxide ,Particulate Matter , Mercury in higher concentration . Ambient air pollutants are comprised of pollutants like primary gaseous pollutants as Carbon Dioxide , Sulphur di-oxide, Sulphur-di-oxide , Carbon Monoxide, Hydrogen sulphide Volatile Organic particulates , Secondary pollutants like Ozone, Per-oxy-acetyl Nitrate(PAN). In this thesis, we in depth discuss in details the Mechanism. Effects the Air Pollutants on the Respiratory Systems these may be divide into Upper Respiratory Symptoms these include sinus, wet cough , Red eyes , dry throat and Lower Respiratory Symptoms including wheezing, shortness of breath, chest discomfort.

1.2 Health Effects of Air Pollution

Air pollution causes an increase in cough, wheezing, shortness of breath or phlegm, pain in the chest. Air pollution exposure causes red/ teary eyes. Air pollution may also cause psychological damage , health-ache due to the prolonged exposure .These effect can be summarised from figure 1.1

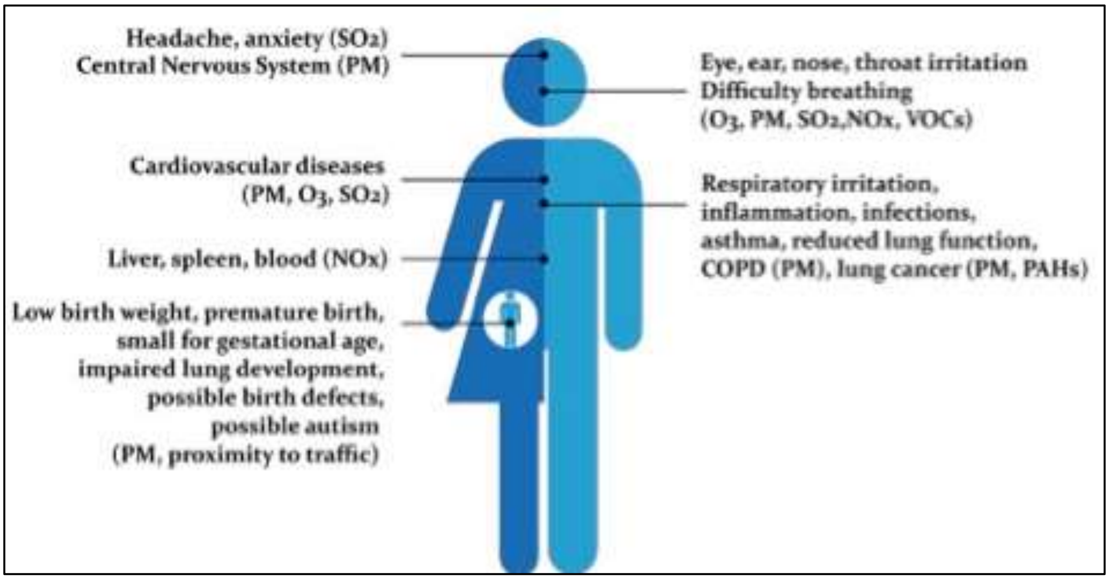


Figure 1.1 – Health Effects of Air Pollution on Human Health

Asthma, a chronic disease of the lungs characterized by inflammation and narrowing of the airways, causes a sensation of tightness in the chest, shortness of breath, wheezing, and coughing. If untreated, asthma episodes can be near fatal or even fatal. Asthma is not currently curable, and damage that is done to lung tissue during asthma attacks may lead to permanent damage.

Bronchitis, Breathing in air pollution and dust or fumes from the environment or workplace also can lead to chronic bronchitis. Certain substances can irritate your lungs and airways and raise your risk for acute bronchitis. For example, inhaling or being exposed to tobacco smoke, dust, fumes, vapours, or air pollution raises your risk for the condition. These lung irritants also can make symptoms worse.

Chronic Obstructive Pulmonary Disease (COPD) is another condition characterized by narrowing of the airways, but these changes are permanent rather than reversible. COPD is caused by exposure to pollutants that produce inflammation, an immunological response. In larger airways, the inflammatory response is referred to as chronic bronchitis. In the tiny air cells at the end of the lung’s smallest passageways, it leads to destruction of tissue, or emphysema. Exposure to air pollutants plays an important role in the development of COPD and the origin and development of acute exacerbations.

People living in urban areas often suffer greater asthma morbidity. Asthma and asthma-related symptoms occurred more frequently in urban than in rural areas, and that difference correlated with environmental risk exposures, healthcare access. Environmental risk factors to which urban adults were more frequently exposed than rural adults were dust mites, high levels of vehicle emissions, and a westernized lifestyle.

In addition, the prevalence of asthma morbidity increases with urbanization. High levels of vehicle emissions, Western lifestyles and degree of urbanization itself, may affect outdoor, and thereby indoor air quality. In urban areas, biomass fuels have been widely replaced by cleaner energy sources at home, such as gas and electricity, but in most developing countries, coal is still a major source of fuel for cooking and heating, particularly in winter.

1.3 Pollutants affecting Health

Particulate Matter consists of product of combustion from burning of fossil fuel in car emission, industries, domestic coal also dispersed dirt and sand. Diesel exhaust is an Asthma trigger especially the tiny particles of size >2.5μm that travels into the lower airways and may trigger asthma and other respiratory conditions.

Nitrogen dioxide and ozone are formed in summer smog and in high concentrations cause inflammation of airway of both Asthmatics and Non-Asthmatics. Nitrogen dioxide and Ozone may make asthmatic airways more sensitive to allergens and so increase inflammation in the airways. However reducing exposure to ozone, oxides of nitrogen and particles does not seem to improve asthma symptoms. Inflammation is the mechanism by which air pollutants damages healthy tissues very complex and under investigation under extensive scientific study. The current clinical evidence strongly suggests exposures to pollution generate inflammation throughout the body and disrupt or destroy many normal physiological processes which are essential for health.

1.4 Objective of the Thesis

1. To study Air Quality of Urban Area in Pune City.
2. To study Spatial and Temporal variations of Air Quality in Pune City.
3. To perform Pulmonary Lung Function Test to find correlation between the lung function and Air Quality.
4. To perform Spatial Interpolation to find out Air Quality for the area not having Monitoring Station.
5. To apply Urban Canyon Model for quantification of increase of Air Pollutants in Urban street due to Vehicular Traffic.

CHAPTER 2
LITERATURE REVIEW

Source apportionment of airborne pollutants is weak in India. Resuspension of dust may contribute significantly but it is rarely quantified. Current results show that there are a number of sources, rather than a single dominant source, for $PM_{2.5}$. Contribution of different sources in relation to season may vary across the cities. Emphasis should be given on these aspects. Similarly there is no reliable emission inventory for PM_{10}, and when available, they often differed considerably for the same city. Efforts should be made to bridge the gaps in our understanding in these respects. Recent studies in Europe and the United States have emphasized the need to explore the effect of ambient air pollution on the cardiovascular system because most people die due to air pollution exposures from diseases of the heart. Unfortunately, very little is known about this problem in India. Therefore, efforts need to be made to investigate the effects of chronic air pollution exposures on the cardiovascular system of the Indian population.

2.1 Spatial Interpolation of Air Pollutants on GIS Platform

739 monitoring station of the EPA for the spatial interpolation for Ozone[4]. They observed that IDW predicted a fairly uniform concentration across the entire county, with a slight decrease toward the coast. Krigged values increased much more strongly from the coast to the inland. Nearest-neighbour interpolations were a patchwork of areas of constant values, and spatial averaging was notable in the number of locations in the county for which interpolated values were not computed. Note that air pollution concentrations are displayed in these maps only at the resolution of BGs, so isopleths reflect BG boundaries and are not smooth.

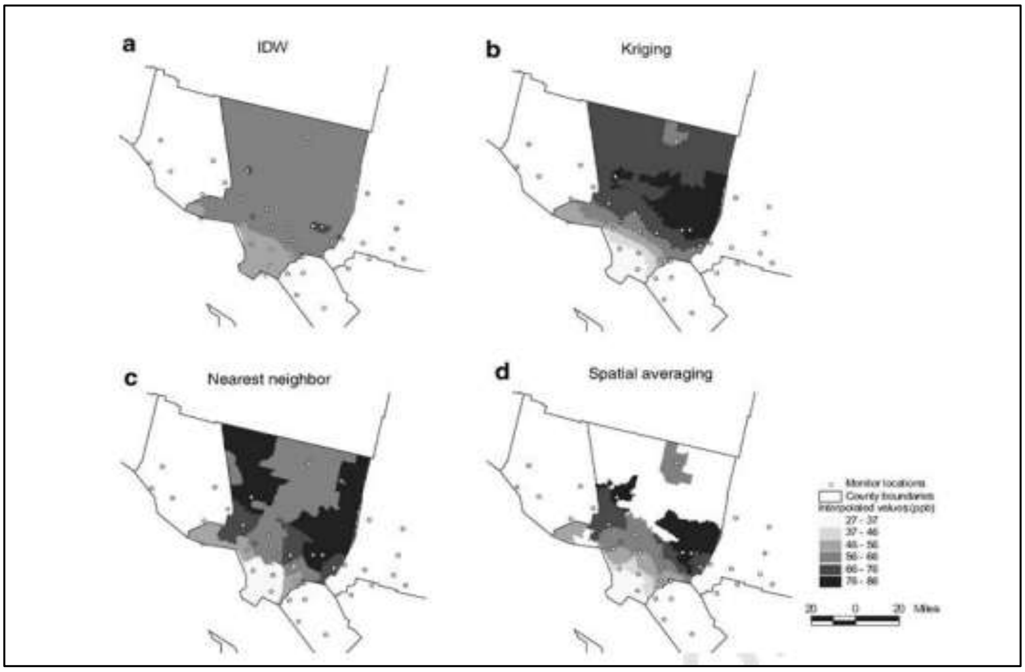


Figure 2.1 - Estimated of four methods for summer daytime O_3 for Los Angeles.

2.1.1 GIS Mapping in representing Air Quality

Concern about air pollution in urban regions is receiving increasing importance world-wide, especially pollution by gaseous and particulate trace metals [5]. Air quality sampling at all the desired location is practically difficult hence it is necessary to have suitable interpolation method to predict data for whole area of interest. Interpolation aims to predict values of un-sampled location based on the sampled data over whole area, which typically results in images or maps. Interpolation is one of the most successful tool in modelling spatial changes of environmental system [6].

2.2 Burden of Disease due to Air Pollution

The quality of the air is the result of complex interaction of many factors that involve the chemistry and the meteorology of the atmosphere, as well as the emissions of variety of pollutants both from natural and anthropogenic sources. According to a World Health Organization's (WHO) assessment of the burden of disease due to air pollution, more than two million premature deaths per year can be attributed to the effects of urban (outdoor /indoor) Air pollution that is mainly caused by burning of solid fuels [7]

More than half of the air pollution driven disease burden is borne by the population of Developing countries. Air quality guidelines are designed to offer guidance in reducing the adverse health impacts of the air pollution. These guidelines are based on expert evaluation of the studies on the health effects of air pollution and current scientific evidence. These guidelines are intended to suggest policy-makers about the gravity of the air pollution problem and to provide appropriate targets for a broad range of policy options for air quality management in different parts of the world [8]. From the air we breathe we are exposed to is a complex mixture of numerous pollutants, including those previously mentioned. Therefore, the health effects of overall air quality are of direct public interest. The data which are available for air pollution and health studies includes population level mortality counts which relate to a study region and point-level measures of these individual pollutants.

2.3 Risks of Air pollution to Human Health

2.3.1 Reproductive toxicity

Particulate matter can significantly increase the adverse reproductive outcomes in both males and females. Studies show relatively low level of air pollution (higher than 40 µg PM_{10} (µg/m^3) result in intrauterine growth retardation (IUGR) in the first gestational month in females and YY8 disomy in the sperms [6]. Investigation for the effects of air pollutants on birth weight mediated by reduced fetal growth among term infants who were born in California showed O_3 exposure during the second and third trimesters and CO exposure during the first trimester were associated with reduced birth weight and an increase of IUGR .

2.3.2 Neurotoxicity

Besides physical health, air pollution exposure may lead to impairment of mental health, because toxic effects of particulate matters on central and peripheral nervous system has been reported. Difficulties with recall, response, concentration, and sleep disorders suggest central nervous system impairment due to vehicular emission [7].

2.3.3 Genotoxicity

Besides affecting the respiratory system, exposure to vehicular emission may cause genetic changes as long-term adverse health effect. Urban atmospheres contain complex mixtures of air pollutants including mutagenic and carcinogenic substances such as benzene, diesel soot, heavy metals and PAHs Particulate matter, especially traffic-related airborne particles, contains a large number of genotoxic/mutagenic chemical substances, which can cause DNA damage and promote malignant neoplasms.

In recent decades, a number of experimental studies that use different short-term assays have provided evidence for the mutagenic potential of airborne PM. Most studies focused their observations on the genotoxicity of extractable organic compounds and mixtures but also on the water-soluble substances (such as metals) and volatile organic compounds. [12,13]

2.3.4 Lung Cancer Risk

Cancer risks in relation to airborne PM after long-term exposure in urban areas have been studied with different epidemiological methodologies, mainly ecologic, cohort, and case-control studies. Several studies in the 1990s collected adequate epidemiological data on air pollution and lung cancer, and their evidence was reviewed [14].

2.3.5 Cardio-Vascular Disease

Air pollution, increased plasma viscosity, hypertension There are reports that indicate air pollution may affect blood pressure. Indeed, high blood pressure (hypertension) is common among persons cumulatively exposed to high level of air pollution [15]. Hypertension is defined as systolic blood pressure at least 140 mm Hg, diastolic blood pressure at least 90 mm Hg, or both [13] .Elevated plasma viscosity, increased heart rate (>80 beats/min), reduced heart rate variability, and increased risk of arterial hypertension have been reported in association with chronic air pollution exposure

2.4 Study by CSE, India on Health Impact of Urban Air Pollution

It is first-ever, national-level economic assessment of environmental degradation in India that establishes the enormous cost air pollution imposes on India’s economy. The cost of serious health consequences from particulate pollution is estimated at 3 per cent of India’s GDP.

Particulate pollution causes 109,000 premature deaths among adults each year

1. 7,500 deaths among children under five annually
2. 48,000 new cases of chronic bronchitis reported each year
3. 370,000 annual hospitalizations
4. 7.3 million emergency room visits/outpatient hospitalizations per year

Table 2.1 Summary of Percentage Contribution to Annual average PM10 concentrations

Sr.No	**Particular**	**Percentage**
1	Vehicle Exhaust	8-16
2	Road Dust	30-50
3	Industries(+kilns)	10-30
4	Domestic	8-20

Table 2.2 Estimated Mortality And Morbidity Due To Air Pollution For Pune 2010

Sr.No	**Mortality & Morbidity**	
1	2010 PM2.5 emissions (tons/yr)	3,6000
2	Premature Deaths	3600
3	Mortality per ton of PM2.5	0.1
4	Adult Chronic Bronchitis	10,800
5	Child Acute Bronchitis	79,250
6	Respiratory Hospital Admission	5,000
7	Cardiac Hospital Admission	1,350
8	Emergency Room Visit	97,800
9	Asthma Attacks (million)	1.2
10	Restricted Activity Days (million)	10.4
11	Respiratory Symptom Days (million)	49.7

More than half of the Air Pollution driven disease burden is borne by the population of developing countries [18]. Air quality guidelines are designed to offer guidance in reducing the adverse health impacts of the air pollution. These guidelines are based on expert evaluation of the studies on the health effects of air pollution and current scientific evidence. These guidelines are intended to suggest policy-makers about the gravity of the air pollution problem and to provide appropriate targets for a broad range of policy options for air quality management in different parts of the world [19]. For purpose of setting Air Quality Standards, air pollutant concentrations should be measured at such monitoring sites that are representative of population exposures. Air pollution levels may be higher in the vicinity of specific sources of air pollution, such as roads, power plants and large stationary emission sources. So the protection of populations living in such situations may require special measures to bring the pollution levels to below the guideline values.

Along with the social and economic development, the scale of urban area as well as the quantity and height of tall buildings increase rapidly. Those structures change outstandingly the wind environment of the urban area. The tall and dense architectural complex reduces the ability of urban ventilation and self-purification, and intensifies urban air pollution and heat island effects in weak wind conditions. On the other hand, in strong wind conditions the tall building may induce local gusts in its vicinity and affect the pedestrian comfort and safety. Then the pedestrian level wind environment problem arises [20]

2.5 Lesson learnt from Air Pollution Episodes in Past

In the major pollution events like London Smog and Los Angeles were mostly due to poor Management of the Urban Agglomerate. The notorious London Smog Event occurred in 1952 is a famous accident that atmospheric pollution seriously harm to human health in history. At that time, households were burning a lot of coal to keep warm and there were many local thermal power stations working all day long. The smog, containing carbon dioxide, carbon monoxide, sulphur dioxide, dust, gas, are released into the atmosphere, and accumulated over the city for the effect of the inversion layer, and finally causing heavy fog weather for several days. These events resulted in heavy mortality clearly indicate that short-term elevated levels of PM and sulphur dioxide are associated with a variety of pulmonary disorders, including mortality [18].

These disastrous episodes prompted many countries in Europe and North America to initiate legislative and regulatory measures to control outdoor air pollution. From the 1960s through 1980s several population-based studies were taken up in the industrialized countries and these investigations confirmed the adverse effects of air pollution on human health [22,23] .

2.6 Health Versus Exposure to Air Pollution

The mean asthma prevalence in this study is reported in 2.38% of 73605 individuals of over 15 years of age [24] . One or more respiratory symptoms were present in 4.3-10.5% subjects. Female sex, advancing age, usual residence in urban areas, lower socioeconomic status, history suggestive of atopy, history of asthma in a first degree relative and all forms of tobacco smoking were associated with significantly higher odds of having asthma [25] .While there is no evidence that air pollution causes asthma, it can trigger attacks in people who have asthma. Many studies have found a link between some air pollutants and the worsening of asthma symptoms.

Important outdoor air pollutants are: particles, sulphur dioxide, nitrogen oxides, ozone, carbon monoxide and lead. A recent European study found that hospital admissions for asthma increase by 1 per cent for every 10 μm/m^3 increase in particles with diameters less than 10 μm(known as PM_{10}). "The health effects of air pollution imperil human lives. This fact is well-documented" Eddie Bernice Johnson Exposure to air pollutants can cause a range of symptoms [22,23,24] . People with lung or heart disease may experience increased frequency and/or severity of symptoms, and increased medication requirements. Each individual will react differently to air pollution. Individual reactions to air pollutants depend on the type of pollutant a person is exposed to, the degree of exposure, the individual's health status (immunity) and genetics. Negative health effects increase as air pollution worsens. During high pollution episode, the healthy people may show more resistant than the individual suffering from the pre-existing health problems.

2.7 Epidemiological Studies

1. 29 European cities with 43 million inhabitants demonstrated that for each 10 μg/m^3 meter increase in 10 μ particulate matter, cardiovascular mortality rose by 69% [25] .In the United States, a survey of 90 cities with 15 million participants revealed a short-term increase in cardiopulmonary mortality of .31% for each 10 μg/m^3 increase in PM_{10} when measured over a 24-hour period [26].

2. Many other studies have also demonstrated significant rises of between .8% and .7% respectively in hospital admissions from heart failure and ischemic heart disease for every 10 μg/m^3 rise in PM_{10}. The studies have also shown an increase of 1.28% and 4.5%, respectively, and risk of heart failure and acute coronary syndromes for every 10 μg/m^3 rise in $PM_{2.5}$[27].

3. There is probable evidence that short-term (hours-days) exposure to PM2.5 increases daily mortality, hospital admissions due to CVD and respiratory diseases [28]. Daily all-cause mortality, 1.23% per 10μg/m^3 .Increased respiratory hospital admissions, all ages, 0.91% per 10μg/m^3 24hr mean. Increased CVD hospital admissions, all ages, 1.9% per 10μg/m^3 24hr mean. The elderly and those with diabetes are at greater risk, and women and obese individuals may be at greater risk .Epidemiological studies were designed to study the associations between cumulative exposures (months, years, decades) to suspended particulate air pollution and long-term effects on morbidity endpoints.

4. Epidemiological research has found consistent and coherent associations between long-term exposure and various health outcomes, such as reduced lung function, respiratory symptoms, chronic bronchitis, relative increase of lung cancer risk, and cardiopulmonary mortality [27].

5. Air pollution and rise in the prevalence of respiratory symptoms .Symptoms are a form of signals that act as an indicator of any underlying illness or disease. Epidemiological studies on respiratory and mental health are generally based on collection of data on the prevalence of respiratory and neurobehavioral symptoms to get an estimate of the disease [30].

Urban air pollution causes five times as many deaths and illnesses as malaria and is almost the largest contributor of regional burden of diseases in South Asia. Information collected till date suggests that the main air pollutant of concern in relation to public health in India is the particulate matter. More recent epidemiological studies have identified that PM_{10} and $PM_{2.5}$ are the principal mediators of health effects of air pollution.

2.8 Interference of Air Pollution on Lung Function during Growth

Although the average growth in FEV_1 was larger in boys than in girls, the correlations of growth with air pollution did not differ significantly between the sexes, as shown for nitrogen dioxide in Figure 2.2. The sex-averaged analysis, depicted by the regression line in Figure 2.2, demonstrated a significant negative correlation between the growth in FEV1 over the eight-year period and the average nitrogen dioxide level (P=0.005). The estimated difference in the average growth in FEV_1 over the eight-year period from the community with the lowest nitrogen dioxide level to the community with the highest nitrogen dioxide level, represented by the slope of the plotted regression line in Figure 2.2, was 101.4 ml

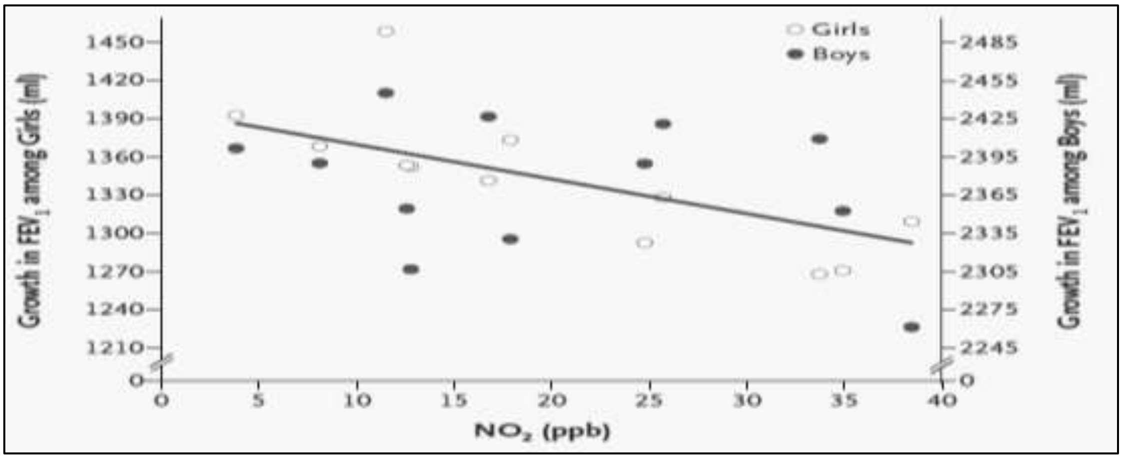


Figure 2.2 Community Specific Average Growth in FEV_1 among Girls and Boys

The author of the current study also note that reduced lung function is a risk factor for complications and death during adulthood and suggest that the effect of these pollution-related deficits in lung function may occur later in life. In fact, studies have shown that long-term, repeated exposure to air pollution is associated with an increased risk of death from cardiopulmonary causes in broad based cohorts or samples of adults [31,32]. The results of this study suggest that residential traffic-related air pollution exposure is associated with reduced expiratory flows in schoolchildren.

The strongest associations were observed between FEV_1 and a correlated set of pollutants, specifically nitrogen dioxide, acid vapour, and elemental carbon. The effects of these pollutants on FEV_1 were similar in boys and girls and remained significant among children with no history of asthma and among those with no history of smoking, suggesting that most children are susceptible to the chronic respiratory effects of breathing polluted air.

	Excess risk% (95% CI per 10µg/m^3)			
	NO_2	SO_2	PM_{10}	O_3
Mortality				
All Causes	0.64(0.36,0.91)	1.36(0.93,1.78)	0.24(0.01,1.46)	-0.11*(-0.37,0.16)
Hospital Admissions				
Respiratory	0.54(0.27,0.80)	0.76(0.34,1.18)	0.50(0.28,0.71)	0.55(0.31,0.79)
Cardiovascular	0.73(0.48,0.98)	1.08(0.72,1.44)	0.37(0.18,0.57)	0.24(0.01,0.47)
Family doctor visits				
Respiratory	3.42(-0.62,7.63)	0.68(-3.03,4.54)	3.28(2.54,4.05)	1.5(-1.18,4.26)
URTIa	1.25(-0.94,3.79)	-0.77(-5.13,3.78)	3.01(1.54,4.50)	1.74(-0.67,4.20)

Table 2.3 Excess Risks and 95% Confidence Interval (CI) for Mortality, Hospital Admissions and Family Doctors Visits per 10µg/m^3 Change in Pollutant

2.9 Harmful Effects of Particulate Matter

The major toxic component of urban air Particulate matter (PM) is a complex mixture of suspended solid and liquid particle in semi equilibrium with surrounding gases. The particle constituents vary greatly in size, composition, concentration, depending on origin and age.

1.PM_{10} consist of Particulate Matter with a diameter upto 10 µm. However, for toxicity studies, the most important particles are those having a diameter of less than 10 µm because they are respirable whereas the larger particles are not.

PM_{10} deposit relatively quickly with a lifetime of less than 2 days, and exposure may lead to adverse responses in the lungs triggering an array of cardio-pulmonary problems [33] . PM_{10} has also been associated with emergency hospital admission for asthma, bronchitis, and pneumonia in older people . For every 10µg/m3 increase of PM_{10}, mortality from all causes increases by 0.51% and from cardiopulmonary diseases by 0.68% [34]. Moreover, the rise in daily mortality from increased concentrations of PM_{10} persists for several days [35].

2.Accumulation mode or fine particles ($PM_{2.5}$) They consist of PM with a diameter upto 2.5 µm. Airborne particles smaller than 2.5 µm ($PM_{2.5}$) are usually called fine particles. These particles may penetrate deep inside the airways and are more strongly linked to adverse health effects .

3.Fine particles are composed mainly of carbonaceous materials (organic and elemental), inorganic compounds (sulphate, nitrate, and ammonium), and trace metal compounds (iron, aluminium, nickel, copper, zinc, and lead). There are potentially thousands of different compounds existing on fine particles that may exert harmful biological effects

4.Despite the variability in PM characteristics, which are believed to influence human health risks, the observed relative health risk estimates per unit PM mass falls within a narrow range of values. Furthermore, no single chemical species appears to dominate health effects; rather the effects appear to be due to a combination of species. Non-PM factors such as socioeconomic status and lifestyle are also believed to affect the health risk. Airborne PM is also responsible for a number of effects aside from human health, such as alterations in visibility and climate.

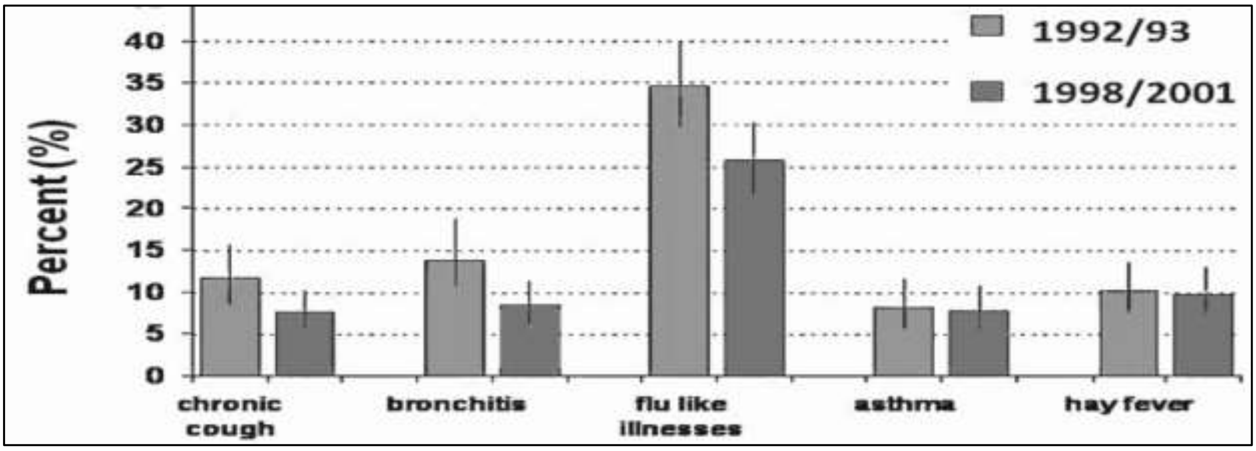
5.With regard to human health, of particular importance are particles that are equal to or less than 10 µm in diameter, because these ultimately enter the lung parenchyma. [36] ,Coarse particles range in size from 2.5 to 10 µm, fine particles are less than 2.5 µm in diameter, and ultrafine particles are less than 0.1 µm. Because of their very small size, particles that are between 0.1 and 2.5 µm are deeply inhaled into the lung parenchyma. If these inhaled particles get deposited in the alveoli they enter the pulmonary circulation and are presumed to also continue to the systemic circulation. These ultrafine particles tend to be short-lived, because they agglomerate and coalesce into larger particles rather quickly.

However, these pollutants exhibit a very high rate of deposition in human alveoli and account for a major proportion of the actual numbers of particles in the lung. They also have a high surface area-mass ratio, and this potentially leads to enhanced biological toxicity [38,39].

6.PM is also associated with autonomic function of heart, including increased heart-rate, decreased heart rate variability and increased cardiac arrythmias. The hypothesis was also strengthened by observations such as urban–rural differences in the case of mortality from lung cancer and chronic obstructive pulmonary disease. [40] calculated the depth of penetration and percentage removal in relation to particle size for the respiratory system beyond the nasal chamber, i.e., from the trachea to alveoli and return. His analysis shows, in accordance with expectations, that depth of penetration increases with decreasing size.

2.10 Implementation of Clean Air Program

Graph 2.3 shows the decrease in prevalence of Chronic Cough , Bronchitis ,Flu like Illness Asthama ,Hay fever after the air improvement program in Switzerland. With improving air quality the prevalence of some respiratory symptoms in schoolchildren decreases.



Graph 2.3 Change in Respiratory symptoms after implementing Air Improvement Program

In general, the evaluation of most of these studies shows that the smaller the size of PM the higher the toxicity through mechanisms of oxidative stress and inflammation. Associations between chemical compositions and particle toxicity tend to be stronger for the fine and ultrafine PM size fractions. Vehicular exhaust particles are found to be most responsible for small-sized airborne PM air pollution in urban areas. With these aspects in mind, future research should aim at establishing a cleared picture of the cytotoxic and carcinogenic mechanisms of PM in the lungs, as well as mechanisms of formation during internal engine combustion processes and other sources of airborne fine particles of air pollution.

Most epidemiological and toxicological studies focused on the inhalation of airborne particulate matter (mainly vehicular exhaust particles) because they found a stronger correlation of mortality and adverse respiratory health effects with fine respirable particles than with other atmospheric gas pollutants.

The basic health effects are

1. excess mortality, mainly among the elderly and chronically ill persons;
2. effects on elderly people with pre-existing cardiopulmonary diseases;
3. exacerbation of symptoms among people with acute and chronic pulmonary disease (bronchitis and emphysema) (hospital admissions); and
4. increased irritation of eye and respiratory system, especially asthma attacks, respiratory infections, and so on.

In the course of investigating and regulating air pollutants, most studies focused on the important air pollutants: sulphur dioxide (SO_2), nitrogen oxides (NOx), acid aerosols (sulfates and nitrate), carbon monoxide (CO), ozone (O_3), and smoke and fine particulate matter [41].

2.11 Single Largest Cause of Avoidable Death - Air Pollution

The Global Burden of Disease (GBD) report is a world-wide initiative involving the World Health Organization (WHO), which tracks deaths and illnesses from all causes across the world every 10 years. WHO reports that in 2012 around 7 million people died - one in eight of total global deaths – as a result of air pollution exposure. This finding more than doubles previous estimates and confirms that air pollution is now the world's largest single environmental health risk. Reducing air pollution could save millions of lives in the world.

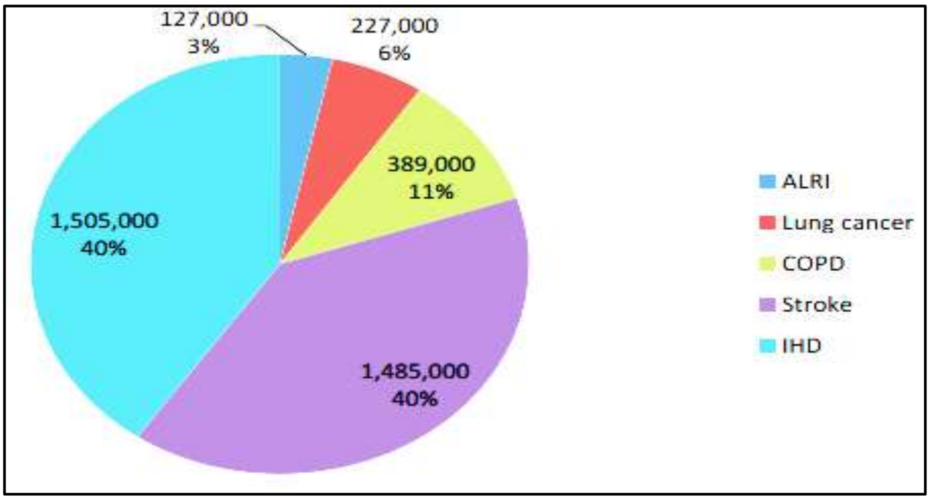


Figure 2.3 - Outdoor Air Pollution-Caused Deaths: WHO Report(2012)

Figure 2.3 shows out of the total diseases caused by Ambient Air Pollution, 40% are Acute lower respiratory diseases such as pneumonia and bronchitis, 40% are Stroke, 11% are Chronic Obstructive Pulmonary disease, 6% are lung Cancer, 3% are Ischaemic heart disease. The major source of man-made pollution comes typically from industry, commerce, domestic cooking and heating, and transportation activities. Urban environment is stressed by a number of common problems such us population, industrial and commercial growth, increasing energy and transportation demands. Worldwide, before 1990 most of the concern and control efforts was given to the industrial sources, but lately it was very clear that the major source for the degradation of the air quality was not any more factories, but the road vehicles, -buses, passengers cars, light and heavy duty trucks or motorcycles. Additionally concern has been given in the last decade to understand and evaluate the impact of such emissions on the population's health. The quality of the air is the result of complex interaction of many factors that involve the chemistry and the meteorology of the atmosphere, as well as the emissions of variety of pollutants both from natural and anthropogenic sources. According to a World Health Organization's (WHO) assessment of the burden of disease due to air pollution, more than two million premature deaths per year can be attributed to the effects of urban (outdoor /indoor) Air pollution that is mainly caused by burning of solid fuels [8].

2.12 Economic Burden due to Air Pollution related Disease

Improvement of air quality is associated with reduction in the number of premature deaths, episodes of acute illness such as asthma attacks and the number of chronic respiratory illness cases.

The economists evaluate the value of avoiding an illness episode as:

1. The value of work time lost due to the illness by the patient or the caregiver, or both
2. The medical cost of treatment
3. The amount paid to avoid the pain and suffering associated with the illness, and
4. The value of leisure time lost due to the illness by the patient or caregiver.

Public Interest have risen over concerns of level of air pollution this has prompted the SPCB's, CPCB and MoEF to strengthen the law for pollution abatement for vehicular and industrial air pollution. Due to the anthropogenic activities damage suffered by the society is increased the present study is

1.To find an optimum level, Marginal cost and Marginal Benefits associated with the abatement of air pollution.

2.Major benefit of the pollution abatement will be “increase general human happiness or improvement in “quality of life ”Hard costs are real and atleast theoretically measurable.

Having found a quantitative association between air pollution and both morbidity and mortality , the Now we represent the Sickness and the death into economic terms. To keep the patients with chronic bronchitis alive and active longer , it seems likely that people would be willing to sums substantially greater than the foregone earnings.

Emitted air pollutants disperse and dilute in the atmosphere and move freely according to the flow of air. Atmospheric dispersion and dilution of air pollutants are strongly influenced by meteorological conditions and topographical features, and urban structures have a great effect on meteorological parameters such as wind direction, wind speed, turbulence, and atmospheric stability [42] .The dispersion and dilution processes result in ambient air pollution, which shows concentrations of different substances varying in relation to time and space [42]. Urban air pollution is affected by the dispersion and dilution processes and is characterized by the spatial variability of pollutants [43].

The Studies have revealed the link between urban design issues, such as compactness or sprawl and air quality, namely atmospheric dispersion and dilution through simulations. Nonetheless, researchers arguing both for and against compact city structure—are still hampered by the absence of empirical evidence to support the effects of increased urbanization on air pollution. This study attempts to draw attention to something that the existing literature has not covered for the most part, underlining that air pollution problems from urban development are mid to long term and cumulative and that air pollution concentrations are determined by dispersion and dilution processes that vary in relation to time and space. If more green areas are secured in the surroundings of a city through compact development, this will increase the dispersion and dilution of pollutants, which can, in turn, result in lower air pollution levels. Vegetation also directly absorbs pollutants through its foliage, thus reducing air pollution levels.

Air pollution in cities is influenced by spatial characteristics (e.g., locational characteristics such as coastal or inland, geological characteristics such as mountains or plains, etc.) and periodic characteristics (e.g., changes in climatic conditions) and, therefore, spatial and temporal variations need to be taken into consideration at the same time in a panel analysis.

Considering that the atmospheric dispersion can be dependent on the location of city (Eg.Whether cities are located inland or close to the coast), the location of city is an important factor. However, it was not used as an independent variable as city location does not change over time. The key explanatory variable among the independent variables was the one representing the compactness of urban development. Urban compactness, in general, was measured by the activity densities within cities. Importantly, this is not the average density of the city as a whole but the relative spatial concentration of the density distribution.

2.13 Air Dispersion Models applied to Street Canyon

The Box model for SPM and sulphur dioxide for Station Road, Kolhapur for weekly average of the pollutant [43]. He found the results of mentioned as Table 2.4 which are quite closer to the Actual Monitored Values in the Street.

Table 2.4 – Comparison between Actual Values and STREET Modelled value

Sr.No	Pollutants	Background Concentration	STREET Box
1	SPM($\mu g/m^3$)	496.57	499.30
2	SO_2($\mu g/m^3$)	27.71	32.92

In this thesis an example of Urban Canyon using Box Dispersion Concept. These Models have a restricted set of boundary conditions the pollutants are set to be content within this set of atmospheric air pollutant concentration is termed as the Accumulation is equal to Input to the box .Output from the box (+ or -) rate of transformation of pollutant.

A single box model and calculated initial dispersion and car induced turbulence, to derive a street canyon sub-model usually called STREET BOX Model [23]. It is based on the assumption that concentrations of the pollutant occurring on the roadside consist of both components, the urban background concentration and the concentration component due to vehicle emissions generated within the specific street. Then, it calculates pollutant concentrations on both sides of the street, taking into account the height of pollutants and distance of the simulated receptor from the kerb.

1.Relatively simple street canyon models (e.g. AEOLIUS, CAR, etc.) only calculate street-level pollutant concentrations, without giving the user the possibility of choosing the height of the simulated receptors. It has been suggested by several authors [44,45,46] that the vertical concentration profiles in a street canyon generally satisfy a law of exponential reduction with height, although more complex patterns depending on the side of the street, the distance from the walls, and the small-scale features of the buildings may be also observed. Simple models for screening applications (e.g. CAR and AEOLIUS Screen) only require the average wind speed over a period of time, assuming that there is no prevailing wind direction.

2.STREET-SRI using data from the San Jose Street Canyon Experiment in California.) created a modified version, called MAPS, which is quite similar in form and performance with the original model. developed a simple box model that yields street-level average CO concentrations in urban canyons under perpendicular and parallel wind conditions[45]. Model results were proved to be in reasonable agreement with field data obtained in Frankfurt (Germany), Madison and Chicago (U.S.A).

3.Measurements of CO and NO_x at different heights and distances from the kerb within three asymmetric street canyons in Guangzhou City (China) [46]. STREET-SRI and a Gaussian plume model were used in this study to obtain CO and NO_x estimates, which were found to be in reasonable agreement with the observed values.

CHAPTER 3
AIR QUALITY MONITORING OF PUNE CITY

3.1 Necessity Monitoring of Ambient Air Quality

• To continue ongoing process of producing periodic evaluation of air pollution situation in urban areas of the country to determine short-term and long-term changes in Air Quality

• To determine status and trend in ambient air quality and effects of air pollution in urban environment as it is the most crucial part of monitoring location

• To estimate the future worsening or improvement of air quality and to obtain the knowledge and understanding necessary for developing preventive and corrective measures.

• To understand the natural cleansing process undergoing in the environment through pollution dilution, dispersion, wind based movement, dry deposition, precipitation and chemical transformation of pollutants generated.

3.1.1 Monitoring Stations under SAFAR Program of IITM

Indian Institute of Tropical Meteorology (IITM), Pune It is a constituent under the Ministry of Earth Sciences, Government of India, is spearheading country's first major initiative named as "System of Air quality Forecasting And Research (SAFAR)". It has been successfully tested during the commonwealth Games 2010 for National Capital Region Delhi. Our vision is to spread the SAFAR to other major cities in India and to put our country in frontiers of Air Quality Forecasting Research. The SAFAR provide location specific information on Air Quality in near real time and its forecast 24 hours in advance. It is complemented by the weather forecasting system designed by IMD, New Delhi. The ultimate objective is to increase the awareness among general public regarding the air quality in their city well in advance so that appropriate mitigation action and systematic measures can be taken up for the betterment of air quality and related health issues. IMD has the Meteorological Data . It has 10 stations in Pune which monitors the air quality.

Table 3.1 Location of IITM's 9 Monitoring Station across Pune City

Code	Location	Institute/Organization name
M1	Pashan	Indian Institute of Tropical Meteorology
M2	Shivajinagar	India Meteorological Department
M3	Pune Airport Lohegaon	Airforce base, Pune
M4	Alandi	MAEER's Maharashtra Academy of Engineering
M5	Katraj	Bharati Vidyapeeth
M6	Hadapsar	Lohiya Udyan, PMC
M7	Bhosari	PCMC
M8	Nigdi	PCMC
M9	Manjri	Vasantdada Sugar Institute

Figure 3.1 – Actual Site of Monitoring Station of IITM

In this GIS Map we have considered 9 Monitoring station by IITM are represented spatially as below figure

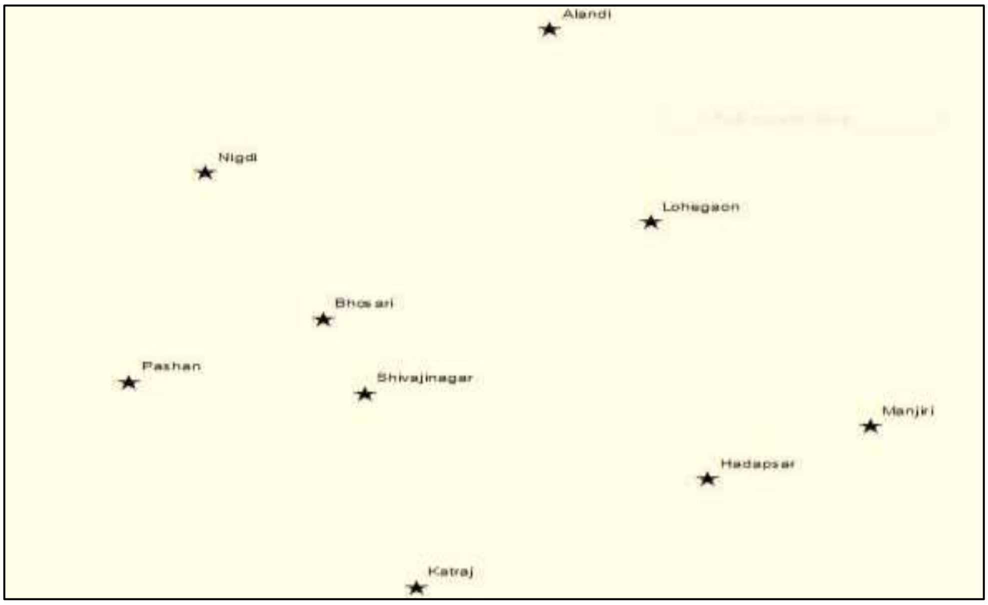


Figure 3.2 – Geo referencing of locations Monitoring Stations on GIS Platform

3.3 Method used in IITM in SAFAR program to Calculate Pollutants

1. Ozone – UV radiation
2. NOx – Chemiluminescence
3. PM – Dispersion Refraction

1.Ozone – UV radiation

UV photometric measurement of surface ozone Surface ozone is routinely measured by in situ techniques. The most commonly used method is that of UV photometry, where ambient air is drawn through a cell in which the absorption of UV radiation is measured at the 254-nm emission line of a mercury lamp. The strong absorption by ozone at this wavelength produces a detectable absorption measurement when ozone is present in the cell. The absorption cell alternately samples ambient air coming directly from the atmosphere and ambient air diverted through a manganese dioxide "scrubber" that converts ozone catalytically to oxygen but leaves all other trace gases intact and the relative humidity almost constant. The UV irradiance is therefore measured in the presence and absence of ozone in the ambient air. The measured irradiance in the presence of ozone, I, is related to the measured irradiance in the absence of ozone, I_0, by the following expression:

$I = I_0 \exp(-\alpha CL)$ [46] where α is the absorption cross-section of ozone at 254 nm (cm^2), C is the concentration of ozone in the cell (molecules cm^{-3}), and L is the length of the cell (cm). By comparing the two irradiance signals it is possible to determine the concentration of ozone in the cell, provided that the length of the cell and the absorption cross-section for ozone are known. Ozone measurements are reported as parts per billion volume or partial pressure. The range of detectability is from 1 to 1,000 ppb.

2.NOx – Chemiluminescence

The chemiluminescence method offers the best results whenever the difficult analysis of the tiny molecule NO in gases is required. Chemiluminescence method allows to detect extremely low concentrations of NOx, being not only fast but also very sensitive and NO specific. The reaction scheme of NOx and O_3 by chemiluminescence is as follows:

$NO + O_3 \rightarrow NO_2 + O_2$ [1]

$NO + O_3 \rightarrow NO_2{}^* + O_2$ [2]

$NO_2{}^* \rightarrow NO_2 + h\nu$ [3]

$NO_2{}^* + M \rightarrow NO_2 + M$ [4]

The radiation emission is in the wavelength between 600 and 3000 nm with an intensity maximum at approximately 1200nm. This chemiluminescence signal is detected photo-electrically. When O3 is present in excess the signal is proportional to the NO concentration of the sample gas. By far the largest portion of the NO_2 * returns to ground state without radiation emission, due to collisions with other molecules (M) [4]. In order to enhance the light yield the pressure in the reaction chamber is reduced. Quenching is an unwanted phenomenon, and the extent to which it occurs depends on the character of the colliding molecule M. For instance water (H_2O) and carbon dioxide (CO_2) quench NO chemiluminescence more effectively than nitrogen (N_2) and oxygen (O_2). In order to measure NO_2 in the sample gas, it has first to be converted into NO. To accomplish this chemical reduction the sample gas is passed through a Converter heated to more than 300 °C (Converter M, Figure 3.3)

If the Converter contains for example carbon as reducing agent, the following reaction takes place: $NO_2 + C \rightarrow NO + CO$ [5]

Modern Converters contain metallic active material, which allows better selectivity of NO_2. Since sample gas normally contains both NO and NO_2, it is possible to measure the sum [NO] + [NO_2] = [NOx] in the Converter channel. Using a catalytic Converter C (Figure 3.3) that also converts amines to NO and a selective Converter M that only converts NO_2, the difference [NOx Amine] - [NOx] can be interpreted under certain conditions as the ammonia [NH_3] concentration.

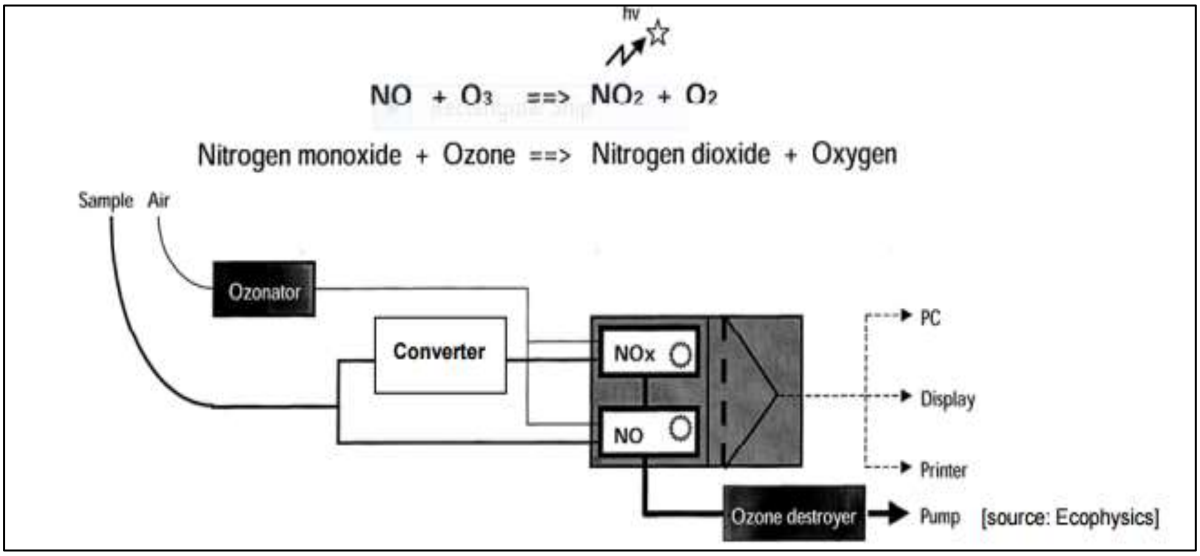


Figure 3.3 – Components of a Nitrogen Oxide Analyse (Chemiluminescence Assembly)

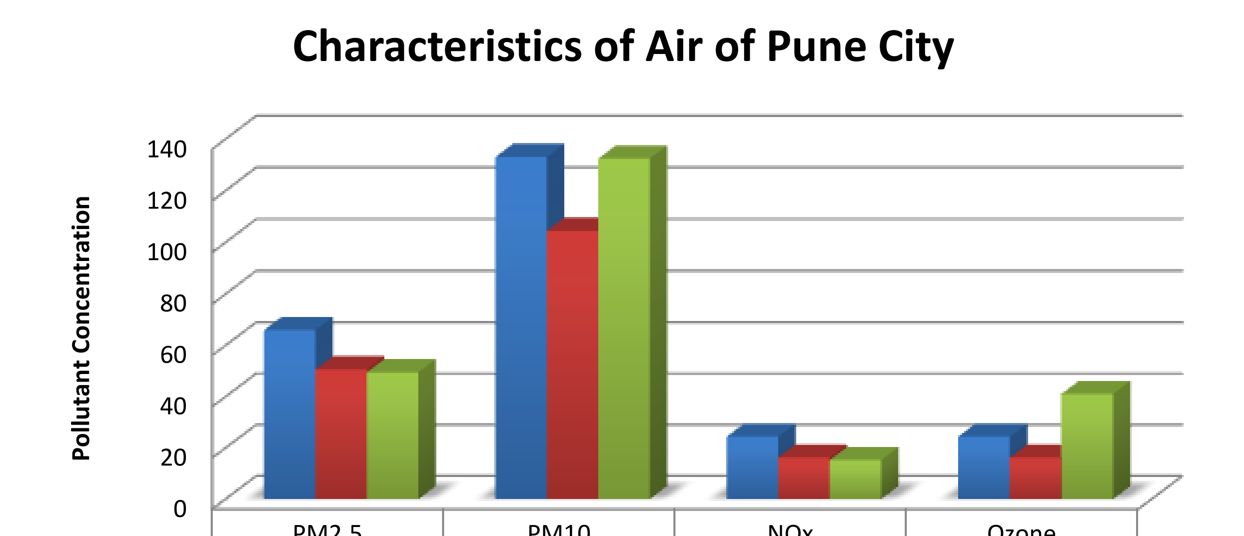
3.Continuous Particulate Monitor(CPM)

The CPM is an optically based unit that uses a microprocessor, transmitter, and receiver. It is a cross-stack measurement requiring two points of access. When light passes between the transmitter and receiver, the momentary absorption of light by the particles causes the receiver to see a modulating signal from the transmitter. This signal modulation increases with and relates to increasing dust concentrations. The signal can be calibrated with a known dust sample or used as a relative monitoring signal. The receiver senses the signal modulation and converts it to a dust concentration with the microprocessor.

CPMs can be used for continuous, in situ monitoring and have excellent sensitivity. CPM systems are easy to install and set up, and all adjustments can be made by the operator. Since CPMs measure signal modulation resulting from moving particles rather than diminishing intensity (brightness) of a light beam, the instrument is unaffected by conditions that cause false readings in an opacity system, such as dirty sensors, misaligned sensors, aging sources, or aging detectors. The CPM will continue to operate with out drift until 93 percent of the transmitted light is blocked. This is normally only 2 percent for typical opacity systems. Also, since it utilizes a diverging light source, it does not rely on lenses and instead uses a small window to separate the sensor electronics from the gas stream. Windows are unaffected by accumulation of dust and also unaffected by misalignment of the sensors. Because of this type of operation, CPMs can monitor even when moisture is present.[47]

3.3 Characteristics of Ambient Air of Pune City

Mentioned in the graph below is the Average Monthly Pollution Concentration across the city It is been done for Months February, March and April for the important Pollutants such as $PM_{2.5}$, PM_{10} , NOx and Ozone.



	PM2.5	PM10	NOx	Ozone
February	66	133.04	24.44	24.44
March	50.6	104.45	16.22	16.22
April	49.49	132.43	15.23	41

Graph 3.1 – Characteristics of Air of Pune City

Units of $PM_{2.5}$ and PM_{10} in $\mu g/m^3$ and Units of NOx and Ozone in ppb

PM2.5 - PM2.5 particles are air pollutants with a diameter of 2.5 micrometres or less, small enough to invade even the smallest airways. These pollutants are above National Average of 60 $\mu g/m^3$ for the Month of February and close to the limit for Month of March, April.

PM10 - PM10 particles less than 10 micrometres in diameter (PM10) are so small that they can get into the lungs, potentially causing serious health problems.

It exceeds the National Ambient Air Quality(NAAQS) Pollution limit for each of February, March and April.

NO_x is a generic term for the mono-nitrogen oxides NO and NO_2 (nitric oxide and nitrogen dioxide). They are produced from the reaction of nitrogen and oxygen gases in the air during combustion, especially at high temperatures .Nitrogen dioxide causes a range of harmful effects on the lungs, including: increased inflammation of the airways; worsened cough and wheezing; reduced lung function; increased asthma attacks. It well below the NAAQS limit of 42 ppb. For NO 1 ppb = 1.25 $\mu g/m^3$

Ozone is molecule of three oxygen atoms bound together (O_3), and it is highly unstable and poisonous . Ozone irritates and inflames the respiratory system at levels frequently found across the nation during the summer months. Breathing ozone may lead to shortness of breath, chest pain; inflammation of the lung lining, wheezing and coughing, increased risk of asthma attacks, and need for medical treatment or hospitalization. It is well below NAAQS limit of 50ppb.For O_3 1 ppb = 2.00 µg/m^3

3.4 Significance of Air Quality Index

The AQI has been developed to provide advice on expected levels of air pollution. In addition, information on the short-term effects on health that might be expected to occur at the different bands of the index (Good, Moderate, Poor, and Very Poor, Critical) is provided. It is expected that the vulnerable people, children and asthmatic people may experience health effects even on Low air pollution days (long-term). This advice applies to anyone experiencing symptoms. The purpose of the AQI is to help you understand what local air quality means to your health. The value of AQI corresponds to concentration of the specific pollutant present in the air at the time of measurement. Different AQI values are generated for various pollutants. To make it easier to understand, the AQI is divided into colour bands as shown in Figure 3.4.

Air pollution has a range of effects on health. It will be interesting to know the air pollution levels at which people need to make major changes to their living habits to avoid exposure. However, nobody needs to fear for going outdoors to perform their routine activities. Severity of the presence of air pollutant depends on its concentration in the air. AQI value represents the concentration of pollutant in the air. AQI level can be interpreted for health impact as:

Table 3.2 Classification of Pollutant in Air Quality Index

COLOUR CODING	AQI Range Index	O_3 (8h avg)	CO (8h avg)	NO2(ppm)	PM10(µg/m^3)	PM2.5(µg/m^3)
Good	0-100	0-50	0-1.7	0-42	0-100	0-60
Moderate	101-200	51-98	1.8-10.3	43-94	101-150	61-90
Poor	201-300	99-118	10.4-14.7	95-295	151-350	91-210
Very Poor	301-400	119-392	14.8-30.2	296-667	351-420	211-252
Very Unhealthy	401-Above	393-Above	30.3-Above	668-Above	421-Above	253-Above

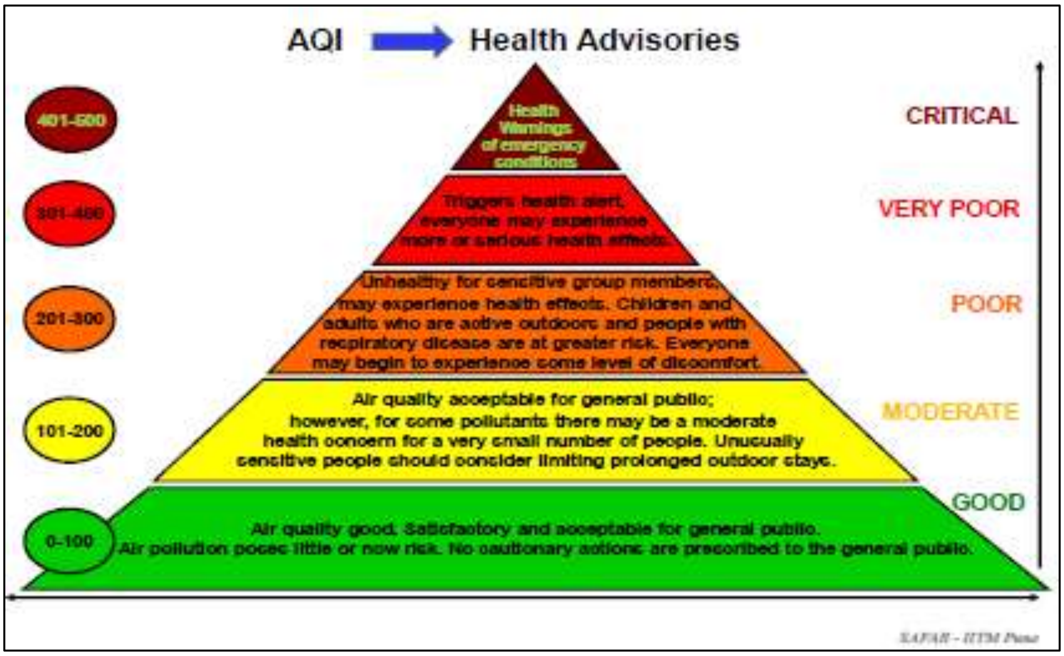


Figure 3.4 – Different categories of AQI different colours and associated impacts

1. Good : AQI (0-100) : Air quality is good/acceptable, there is very little or no risk for general public. Precautionary measures are not required.

2. Moderate : AQI(101-200) : Air quality is acceptable for general public. It will be better if sensitive people like patients suffering from respiratory and heart diseases avoid prolonged outdoor activities.

3. Poor : AQI(201-300) : General public may experience some discomfort/health effects during regular activities. It is unhealthy for a group of sensitive people, children and older people may get affected by outdoor activities by environmental exposure.

4. Very Poor : AQI (301-400) : Unhealthy for general public, everyone will experience more or less health effects. There is a need to take precautionary measures.

5. Critical : AQI (401 -500) : It is an emergency alarm for everyone. Immediate precautionary measures are required.

CHAPTER 4
SPATIAL INTERPOLATION OF AIR POLLUTION USING GIS

4.1 GIS to represent Urban Air Quality

GIS can be used as a decision support system in order to help the mangers of public health. In recent years, many applications of GIS in public health are developed that include management of available health resources, prediction, simulation and management of epidemics and monitoring and control of diseases. On the other hand, time plays an important role in health affairs especially in the time of disasters. Therefore, access to useful spatial information and making proper decisions, based on analysing such information, will facilitate reaching desired results in shorter time and less cost. The temporal variation of concentration of pollutant throughout the day varies with the influence of local wind parameters such as direction and speed and other meteorological aspects. On the other hand, changing pattern of vehicular traffic and industrial activities also act as a factor for variation in pollution levels.

Spatial Interpolation of the GIS Toolset is applied for environmental issue like air pollution, air pollution levels can be visualized the spatially distributed over the city, Pune from the 9 monitoring stations setup by the IITM agency. The characteristics of an interpolated surface can be controlled by limiting the calculation of output cell values. Specifying the maximum number of points to be sampled will return the points closest to the output cell location until maximum number is reached. [48] states that critical analysis is possible by ANOVA Test for the Critical Pollutants for the monitoring stations

Geographical information systems (GIS) offer powerful technologies for use in integrated assessments. Their power comes from the fact that they provide a means:

Functional Components of GIS are namely

1. Data acquisition and data verification
2. Data storage and database management
3. Data transformation and analysis
4. Data output and presentation
5. User interface

This can be applied environmental point of view as

- To link and integrate different data sets from different sources - e.g. between different environmental phenomenon or between environment and population;
- To explore and analyse spatial patterns and relationships in the data - e.g. to estimate numbers of people potentially exposed because they live close to emission sources;
- For spatial modelling - e.g. to simulate propagation and dispersion of environmental pollutants;
- For mapping and other forms of visualisation of spatial data.

4.2 Uses of Spatial Interpolation

- To estimate values where there is no monitoring station is available
- Visualization of complex point data where setting up monitoring is difficult
- Analysis of trends over space and time across the study area
- Creation of discrete boundaries between values

Many epidemiological studies examining the relationships between adverse health outcomes and exposure to air pollutants use ambient air pollution measurements as a proxy for personal exposure levels. When pollution levels vary at neighbourhood levels, using ambient pollution data from sparsely located fixed monitors may inadequately capture the spatial variation in ambient pollution. A major constraint to moving toward exposure assessments and epidemiological studies of air pollution at a neighbourhood level is the lack of readily available data at appropriate spatial resolutions.

Air pollution in urban environments has serious health and quality of life implications. A wide variety of anthropogenic air pollution sources increase the levels of background air pollutant concentrations, leading to the deterioration of the ambient air quality.

The first approach involves the numerical simulation of atmospheric dispersion based on the current understanding of physics and chemistry that govern the transport, dispersion and transformation of pollutants in the atmosphere. The modelling process typically requires a set of parameters such as meteorological fields, terrain information along with a comprehensive description of pollution sources. An alternative approach is based on statistical analysis of pollutant concentrations collected from air quality monitoring networks commonly deployed in urban areas. The reasoning of the statistical approach is that physical processes are likely to induce correlations in air quality data collected over space and time.

Statistical models generate predictions by exploiting these spatio-temporal patterns, enabling the estimation of pollutant concentrations in unmonitored locations.

4.2.1 Spatial data types

While, in practice, almost all real-world phenomena comprise *volumes* (i.e. they have dimensions of height, width and depth), the data that we use to describe them often represent them in different ways. Three fundamental spatial structures can be recognised:

- points - e.g. a sampling location, a point emission source, or a residential address;
- lines - e.g. the centreline of a roadway or stream;
- areas - e.g. an area of woodland or industrial land, a census tract, a country.

Each of these, however, can be represented either as an irregular structure or as a regular one. Most natural phenomena are somewhat irregular: for example, sampling locations are spread unevenly across the landscape, roads are laid out haphazardly, and administrative regions are bounded by irregular boundaries. In GIS, these irregular structures are all represented by vector data. It is advantageous to present data in a regular form - as an array of points, a lattice of lines, or a grid of regular cells.

In GIS, these are all forms of raster data. Although presenting data in this form may involve some degree of distortion of reality, it has several major advantages. In particular, it makes computation much more efficient (and therefore allows larger data sets to be analysed) and, as a basis for mapping, improves interpretability of the results. For these reasons, many of the most powerful GIS techniques operate in raster form, and in many cases it is helpful to present results as gridded maps.

Spatial interpolation is the procedure of estimating the values of the variable under study at unsampled locations, using point observations within the same region. Statistical interpolation methodologies are applied in air pollution modelling for estimating the spatial distribution of pollutants, based on data provided from an existing air quality monitoring network. Such networks consist of a number of irregularly distributed stations and therefore the issue of air pollution spatial interpolation is essentially a problem in the field of scattered data approximation. The monitoring sites are typically located to detect high concentrations and although such a configuration is appropriate for identifying the maximum potential exposure and risk, in many cases it fails to describe the spatial variability of air pollution. Recent developments in the design and the modification of existing air quality monitoring networks address this issue [48,49] and propose methodologies for an optimum configuration of monitoring sites used for more reliable and cost-effective spatial predictions

4.3 Methodology

4.3.1 Settings on ArcGIS

There are 4 methods of Spatial Interpolation Available in the ArcGis Toolset, in Spatial Interpolation Category .The following settings are to be done in the GIS projection co-ordinate system for the Pune city Maharashtra region it is termed as WGS_1984_UTM_Zone_43N in which WGS Spatial reference number in which the Indian topography is best represented and 43N is for Maharashtra region representation.

4.3.2 Data for the Monitoring Stations

Table 4.1 - February - 2015 Air Quality Data

Pollutant	**Pashan**	**SN**	**Lohegaon**	**Alandi**	**Katraj**	**Hadapsar**	**Bhosari**	**Nigdi**	**Manjri**
PM10	112.55	150.82	113.71	132.66	132.66	152.87	164.97	88.06	149.07
PM2.5	51.16	63.03	70.34	55.34	72.97	92.29	64.30	39.53	85.09
Ozone	42	37	50	52	53	31	37	44	53
Nox	12.71	31.76	46.51	29.86	16.53	56.54	4.27	12.39	26.32

Table 4.2 - March - 2015 Air Quality Data

Pollutant	**Pashan**	**SN**	**Lohegaon**	**Alandi**	**Katraj**	**Hadapsar**	**Bhosari**	**Nigdi**	**Manjri**
PM10	93.20	127.21	96.44	107.32	107.32	110.54	125.45	72.02	100.55
PM2.5	45.86	56.71	63.29	40.33	68.28	67.02	43.66	25.59	44.68
Ozone	34	39	47	49	51	34	38	38	52
NOx	10.04	30.09	34.96	14.38	15.20	13.99	6.03	10.12	11.15

Table 4.3- April - 2015 Air Quality Data

Pollutant	**Pashan**	**SN**	**Lohegaon**	**Alandi**	**Katraj**	**Hadapsar**	**Bhosari**	**Nigdi**	**Manjri**
PM10	93.20	127.21	96.44	107.32	107.32	110.54	125.45	72.02	100.55
PM2.5	45.86	56.71	63.29	40.33	68.28	67.02	43.66	25.59	44.68
Ozone	34	39	47	49	51	34	38	38	52
NOx	10.04	30.09	34.96	14.38	15.20	13.99	6.03	10.12	11.15

4.4 Methods of Spatial Interpolation on GIS Platform

4.4.1 Inverse distance weighting (IDW)

Inverse distance weighting (IDW) combines the notion of proximity with that of gradual change of the trend surface. IDW relies on the assumption that the value at an unsampled location is a distance weighted average of the values from surrounding data points, within a specified window. The points closest to the prediction location are assumed to have greater influence on the predicted value than those further away, such that the weight attached to each point is an inverse function of its distance from the target location. Interpolation weights in IDW are computed as a function of the distance between observed sample sites and the site at which the prediction has to be made [50]. As observed values that were closer to the point of interest were more heavily weighted, a larger search window could be used that still preserved some of the local variations in pollutant levels. Data from all monitors within a 250 km search window were included in the IDW interpolation for both PM_{10} and O_3. The 250 km radius was chosen to ensure that all block groups in the counties of interest had an interpolated value for both O_3 and PM_{10}. We have tested other smaller windows (60 and 100 km), but through cross validation, we found that the accuracy of interpolation was not too sensitive to the window size. However, choosing smaller windows will leave some of the block groups of interest without an estimated value.

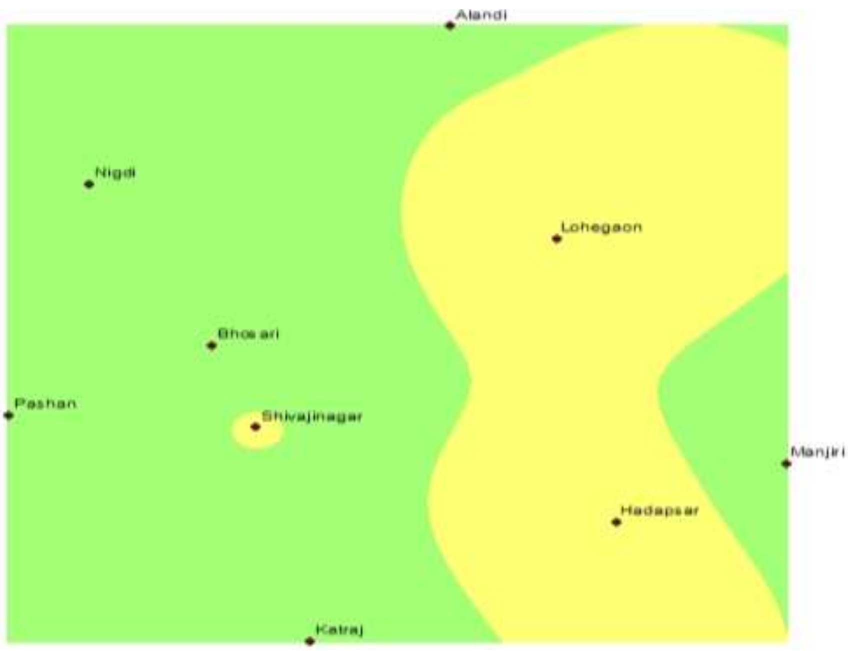


Figure 4.1– Spatial Interpolation using Inverse Distance Weighing Method

4.4.2 Kriging

Kriging interpolation schemes are the fundamental tools in the field of spatial statistics, developed by the founder of geostatistics G. Matheron and named after D.G. Krige who proposed the technique for mining applications [51]. The Kriging interpolation schemes are stochastic, local, gradual and exact interpolators. The Kriging methodology includes two stages: the analysis of the spatial variation and the estimation of the target variable, which is also based on the weighted average approach. The plot of the semivariance versus the lag distance is the empirical variogram, which is subsequently modelled by a parametric model. The most common models are the linear, the circular, the spherical, the exponential, the Gaussian or a nested model of one or more of the above. The characteristic parameters of the variogram are the sill, which is the semivariance value at the plateau of the variogram, representing the distance where there is no correlation between the observations, the range, which is the lag where the semivariance is equal to the sill and the nugget which represents theoretically the minimum variance and is the semivariance value at zero lag distance .

The Kriging is best linear unbiased estimator, and its estimates are based on the variogram model and the values and location of the measured points [52]. The Kriging interpolation weights are chosen using the modelled Advanced Air Pollution variogram so that the estimate is unbiased and the estimation variance is less than any other linear combination of the observed values. The most common Kriging methods are the Simple Kriging, which assumes a known constant mean, Ordinary Kriging, which assumes that there is an unknown constant mean, estimated from the data and Universal Kriging which assumes that there is a trend in the surface that partly explains the data's variations [52] . The spatial variation of air pollution measurements is complex but is not generally unstructured. It is almost always spatially dependent on some scale, with this dependence referred to as spatial autocorrelation [38,39]. This structure may then be overlain by more or less random local variation. The whole can be described by a variogram that summarizes the variation.This one is kind of in between—because it fits an equation through point, but weights it based on probabilities.

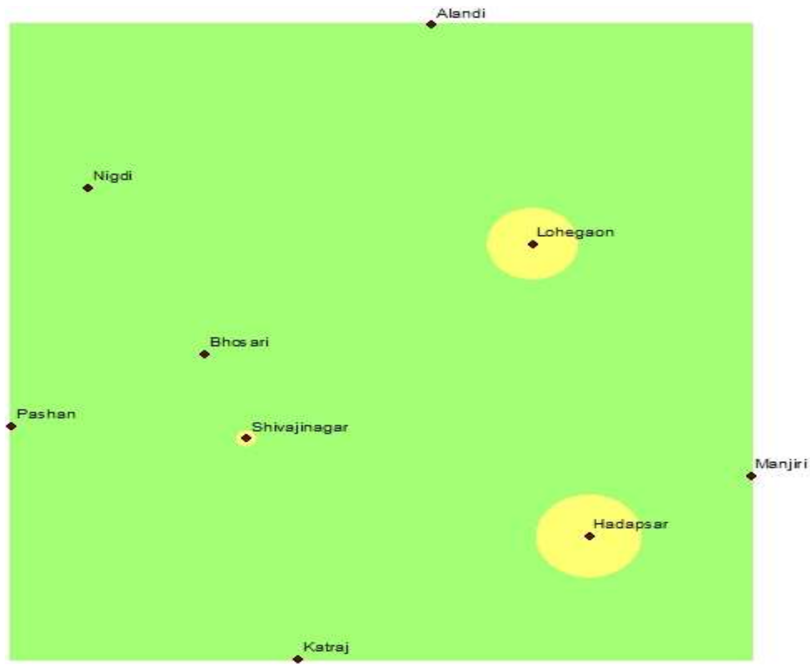


Figure 4.2 – Spatial Interpolation using Kriging Method

4.4.3 Nearest Neighbour

Each Monitoring Station is assigned the air concentration level of the monitor nearest to its centroid regardless of how far away the monitor was located. This eliminated the search radius as a parameter in the interpolation [53,54] .In this method, the local coordinates define the amount of influence any scatter point will have on the output cells. Nearest-neighbour interpolation (also known as proximal interpolation or, in some contexts, point sampling) is a simple method of multivariate interpolation in one or more dimensions. Interpolation is the problem of approximating the value of a function for a non-given point in some space when given the value of that function in points around that point.

The nearest neighbour algorithm selects the value of the nearest point and does not consider the values of neighbouring points at all, yielding a piecewise-constant interpellant. The algorithm is very simple to implement and is commonly used in real-time 3D rendering to select colour values for a textured surface. Spatial Interpolation is been done using Nearest Neighbour on Figure.No.4 given below.

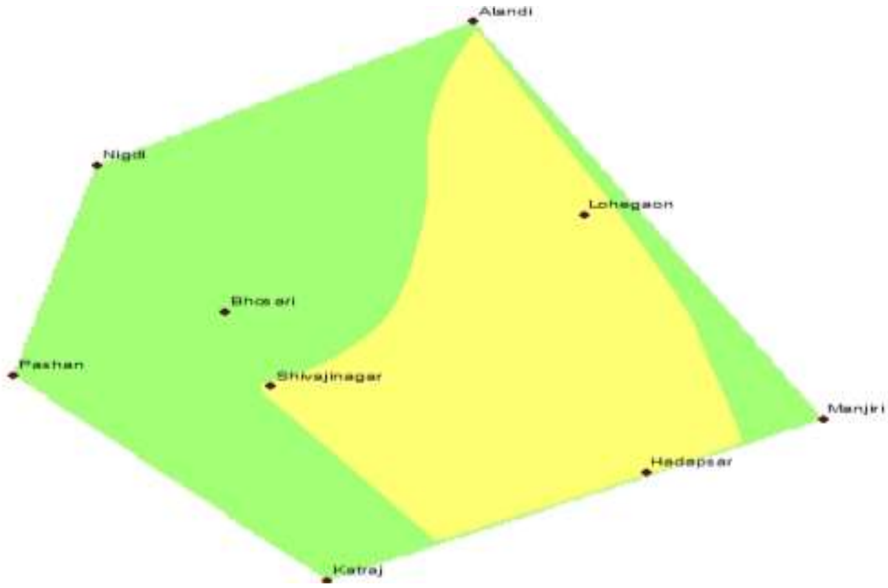


Figure 4.3 – Spatial Interpolation using Nearest Neighbour Method

4.Splining

Note from Figure.4.4 how smooth the curves of the terrain are; this is because Spline is fitting a simply polynomial equation through the points .This fits a curve through the sample data assign values to other locations based on their location on the curve.

Thin plate splines create a surface that passes through sample points with the least possible change in slope at all points, that is with a minimum curvature surface Spline estimates values using a mathematical function that minimizes overall surface curvature. This results in a smooth surface that passes exactly through the input points. Conceptually, it is like bending a sheet of rubber so that it passes through the points while minimizing the total curvature of the surface. It can predict ridges and valleys in the data and is the best method for representing the smoothly varying surfaces of phenomena such as temperature. There are two variations of spline—regularized and tension. A regularized spline incorporates the first derivative (slope), second derivative (rate of change in slope), and third derivative (rate of change in the second derivative) into its minimization calculations. Although a tension spline uses only first and second derivatives, it includes more points in the spline calculations, which usually creates smoother surfaces but increases computation time.

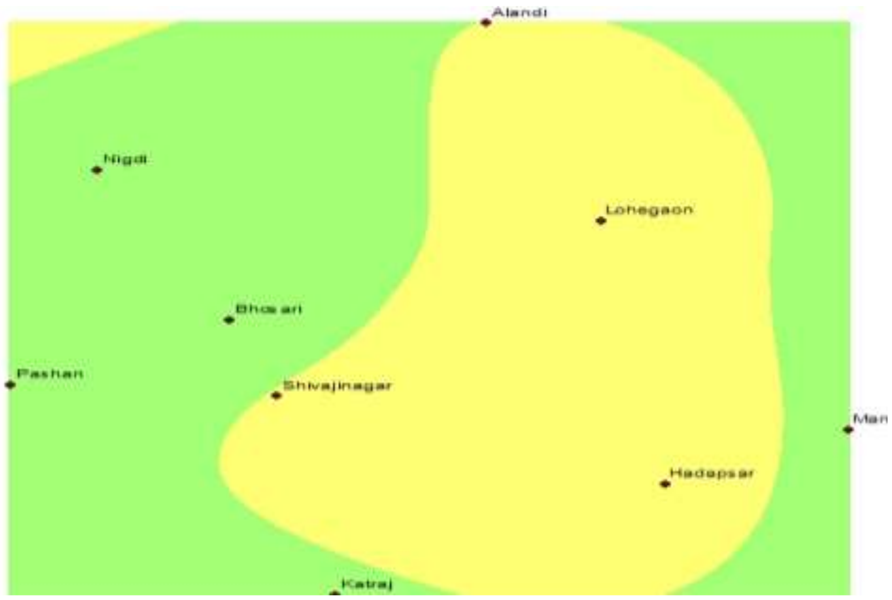


Figure 4.4– Spatial Interpolation using Splining Method

4.5 Results and Discussion

GIS Maps representing the Air Quality characteristics using Most suitable Spatial Interpolation GIS Method .The representation of the air quality GIS Map in different colour schemes representing as per its Air Quality Index according to this table given below

4.5.1 Representation of Monthly Air Quality on GIS platform

Representation of Air Quality for Pune City on GIS Platform. A small number of air quality monitors greatly reduces the availability of Kriging and Splining as a suitable Method for Interpolation .These Method require the greater number of monitoring stations for a particular map. Spatial Interpolation is been done using Inverse Distance Weighing Method.
The Pollutants for which the Interpolation is been done are PM_{10} , $PM_{2.5}$, Ozone ,NOx distribution over the city is done so that we can shortlist the causes of pollution. Monitoring of Ozone is important as it affects the human health in adverse manner causing chest pain, coughing, Asthma Attack[55].

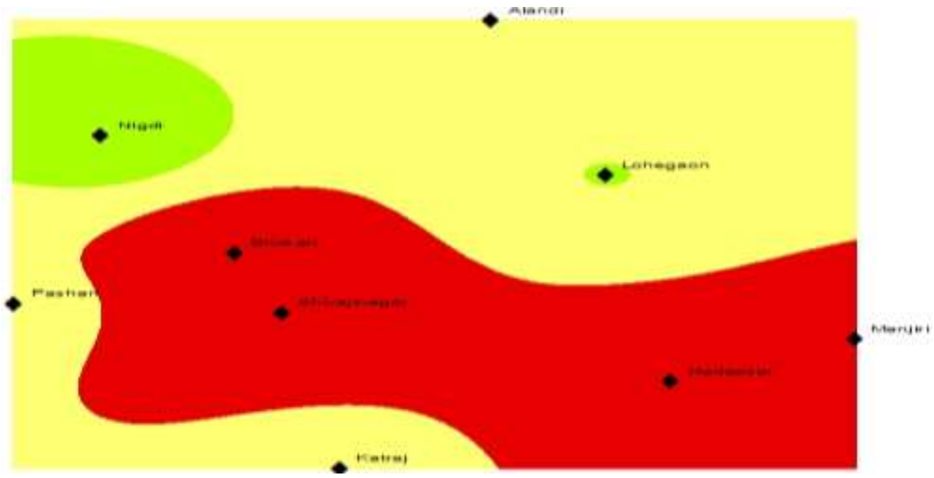


Figure 4.5 GIS Map for PM_{10} representing February

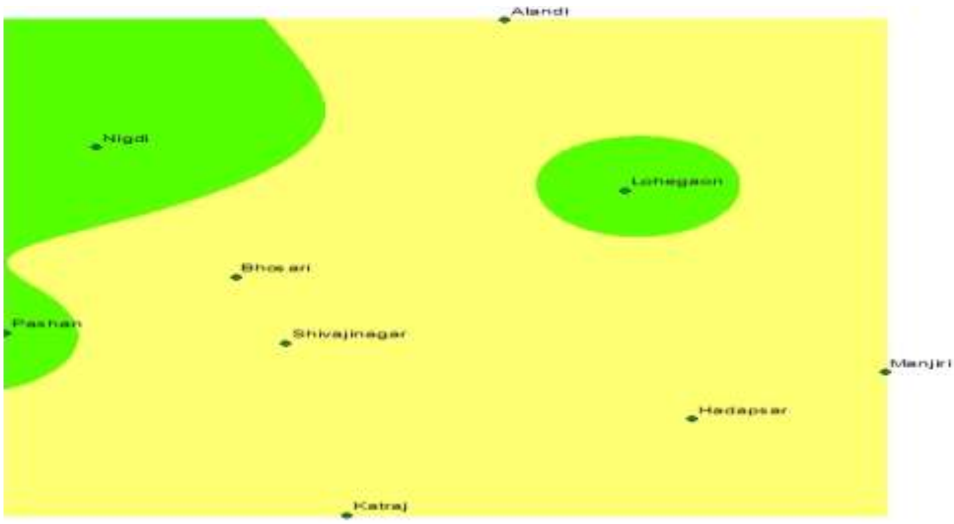


Figure 4.6 GIS Map for PM_{10} representing March

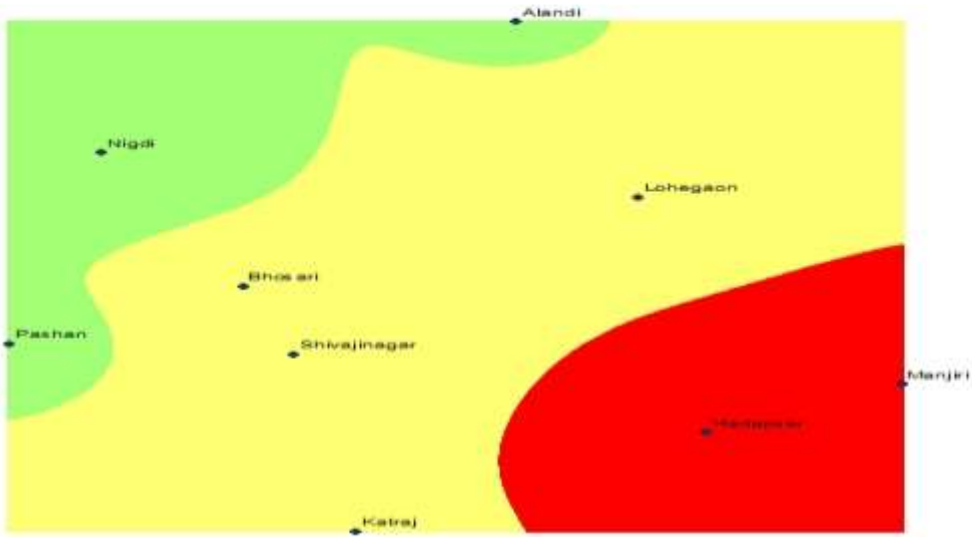


Figure 4.7 GIS Map for $PM_{2.5}$ representing February

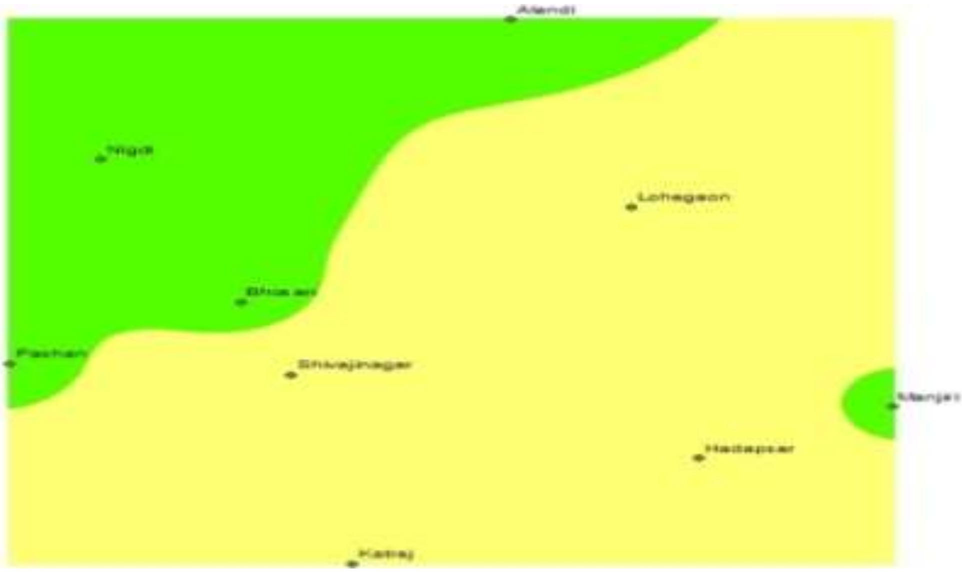


Figure 4.8 GIS Map for $PM_{2.5}$ representing March

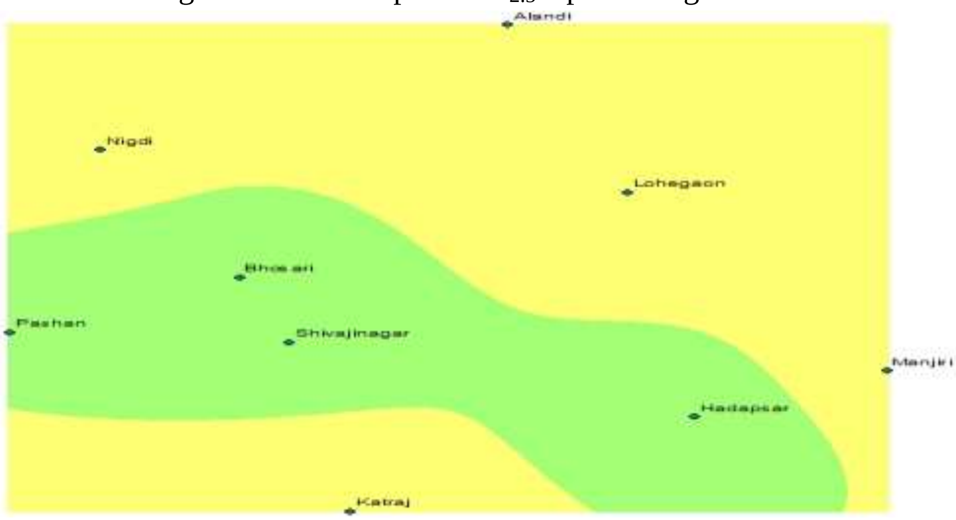


Figure 4.9 GIS Map for Ozone representing February

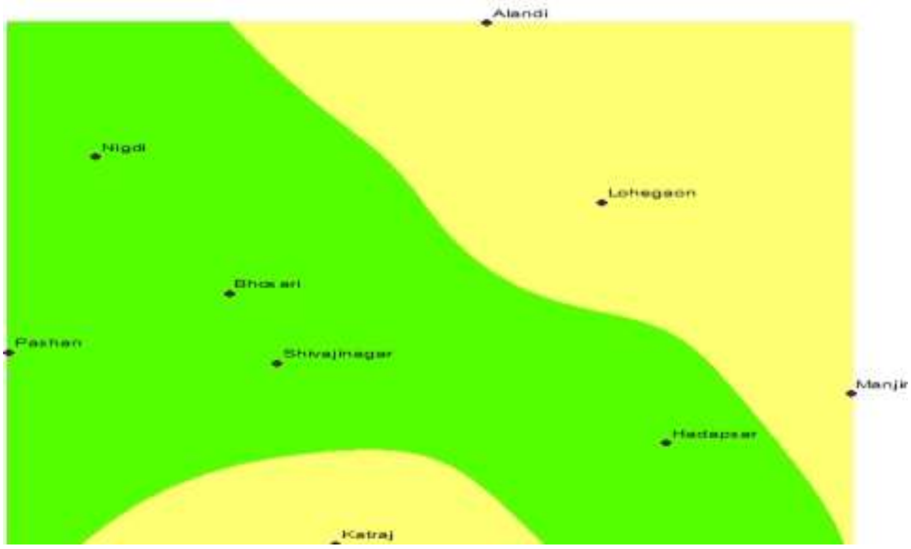


Figure 4.10 GIS Map for Ozone representing March

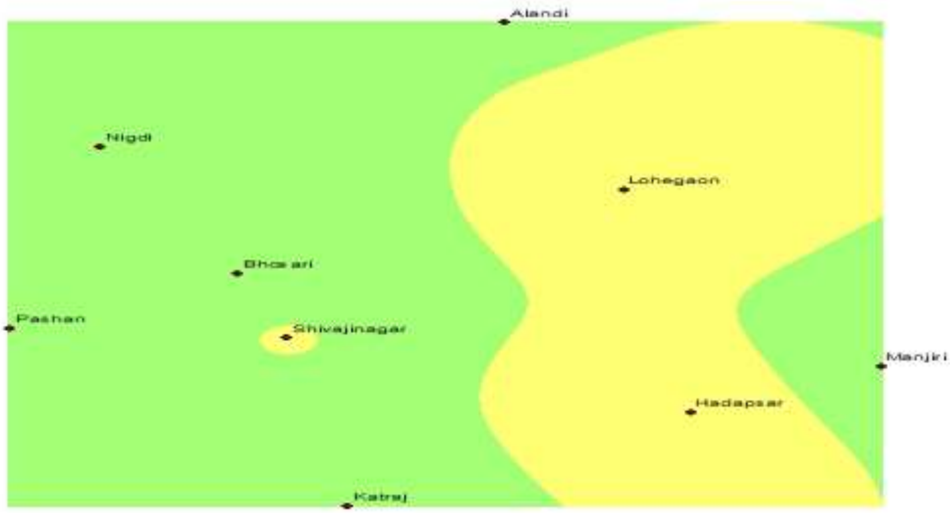


Figure 4.11 GIS Map for NOx representing February

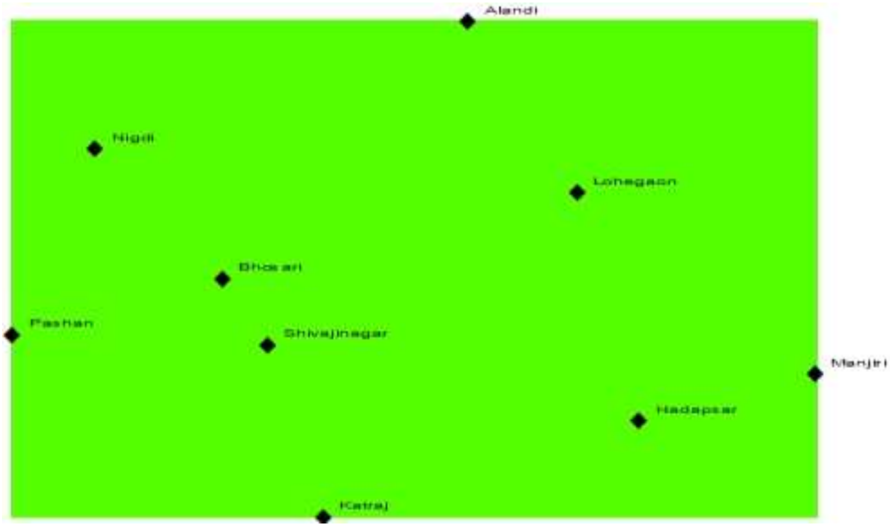


Figure 4.12 GIS Map for NOx representing March

The concentrations of the PM_{10} and $PM_{2.5}$ both are higher than the normal range so there are chances of people suffering from the diseases such as lung cancer, cardio vascular mortality. Particulate Matter can also cause Asthma and exacerbate Asthma. PM_{10} particles deposit mainly in the upper respiratory tract while fine and ultrafine particles are able to reach lung alveoli. So far, no single component has been identified that could explain most of the PM effects. Among the parameters that play an important role for eliciting health effects are the size and surface of particles, their number and their composition. However, their major components are metals, organic compounds, material of biologic origin, ions, reactive gases, and the particle carbon core The two major precursors for ozone are volatile organic compound (VOCs) and NOx. The heavily industrialized area on the ship channel to the east of the city releases large quantities of VOCs and moderate quantities of NOx.

There are different types of data which you then can collect for creating thematic air quality maps: climatically data; air quality data from monitoring stations; data from pollution

sources, such as industries, waste management, traffic; social data, such as health, well-being or mortality; All this information can be plotted onto maps. Such maps will give an overview of the impact of emissions in the different areas of the city. The study of weekdays and weekends is peculiar done for the hypnotised major contributor in Vehicular traffic air pollution. People generally go for work at weekdays so the traffic is greater and greater amount of emission in weekdays. [56] analysed of ambient air quality on public holidays occurring per year at Delhi. The pollution levels of parameters reduces by 3-4% for O_3 and PM; 11-14 % for NO, CO and NO_2 on a holiday w.r.t. the pollution level of the same parameter during working days. This is due to lessened traffic during the public holidays
The pollution at the Weekdays is greater than that at the weekends at all time of the week expect for the tourist location in Alandi and the Airport Area where the pollution is greater at weekends owing to greater traffic volume

(a) Air Quality Weekdays Typical Peak Hours (average of Monday to Friday)
(b) Air Quality Weekends Typical Peak Hours (average of Saturday and Sunday)

4.5.2 Comparison of Weekend and Weekdays Air Quality on GIS platform

Change in the Air Quality as per different times of the day can be represented as We have considered one of the Most Hazardous Pollutant $PM_{2.5}$ for Spatial Interpolation in µg/m^3

Table 4.4 –Average Concentration of $PM_{2.5}$ on the weekdays at different times of day

Locations	weekdays 06:00	weekdays 12:00	weekdays 20:00	weekdays 00:00
IITM	59.024	104.09	41.878	54.498
IMD	58.874	99.818	54.042	90.03
Airport	105.506	116.274	39.126	96.052
Alandi	45.804	81.688	35.024	81.378
Katraj	86.9	168.514	59.368	83.776
HDP	95.31	163.632	61.318	115.868
Bhosari	96.798	98.898	48.538	80.042
Nigdi	63.916	75.108	43.72	61.742
VSI	110.68	123.23	47.706	107.316

Table. 4.5 –Average Concentration of PM2.5 on the weekdays at different times of day

Locations	weekends 06:00	weekends 12:00	weekends 20:00	weekends 00:00
IITM	47.86	100.49	46.625	47.625
IMD	51.48	110.15	43.605	61.42
Airport	110.89	104.93	59.235	89.995
Alandi	55.51	94.78	45.465	47.91
Katraj	100.07	110.645	61.31	79.765
HDP	103.74	135.155	63.88	86.455
Bhosari	108.775	110.37	57.955	77.41
Nigdi	68.695	89.12	34.43	47.475
VSI	124.65	129.805	70.03	78

GIS Maps is represented in such a way that classes been divided into 9 equal intervals as per their concentration.

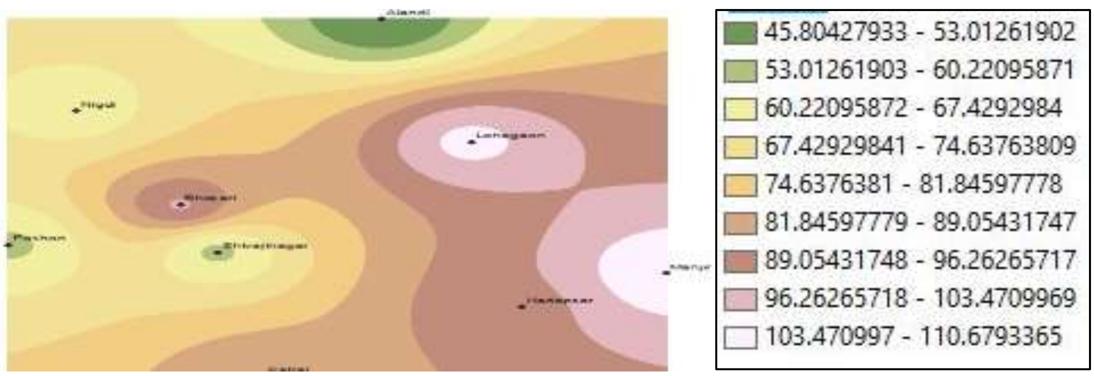


Figure 4.13 –Weekdays Spatial Interpolation of $PM_{2.5}$ at 06:00

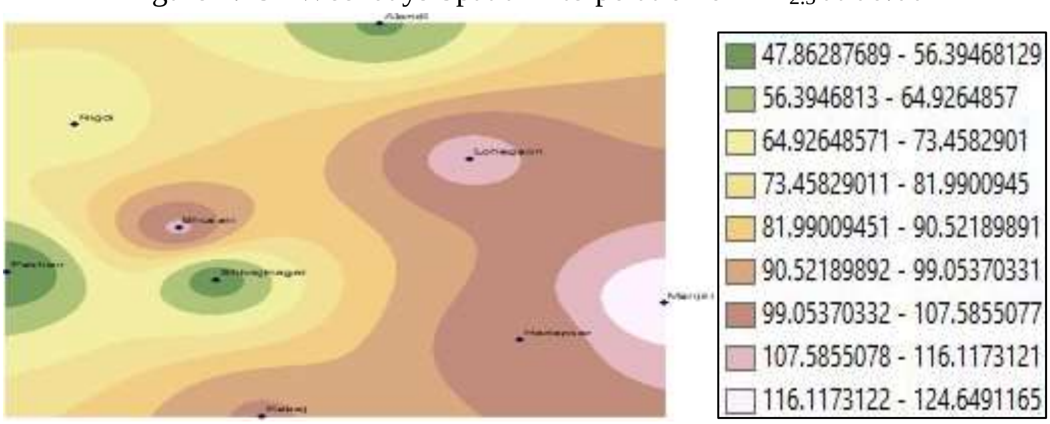


Figure 4.14 –Weekends Spatial Interpolation of $PM_{2.5}$ at 06:00

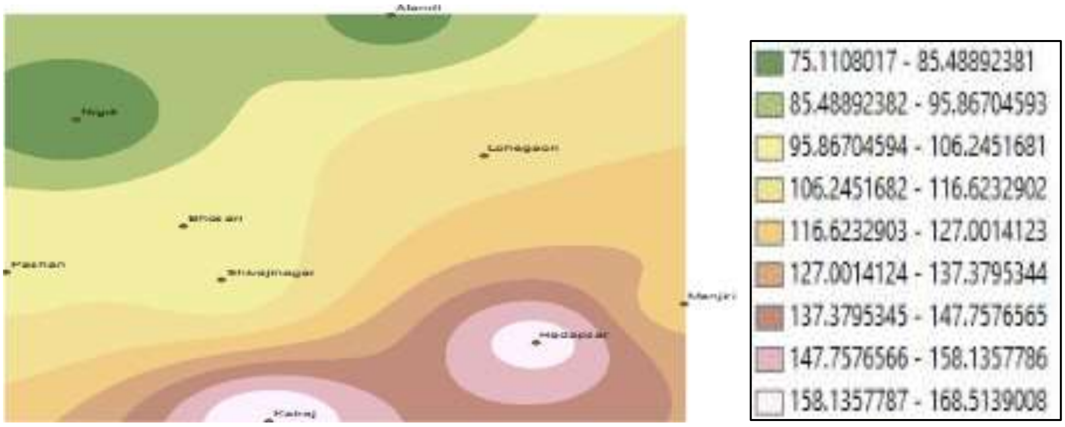


Figure 4.15 –Weekdays Spatial Interpolation of $PM_{2.5}$ at 12:00

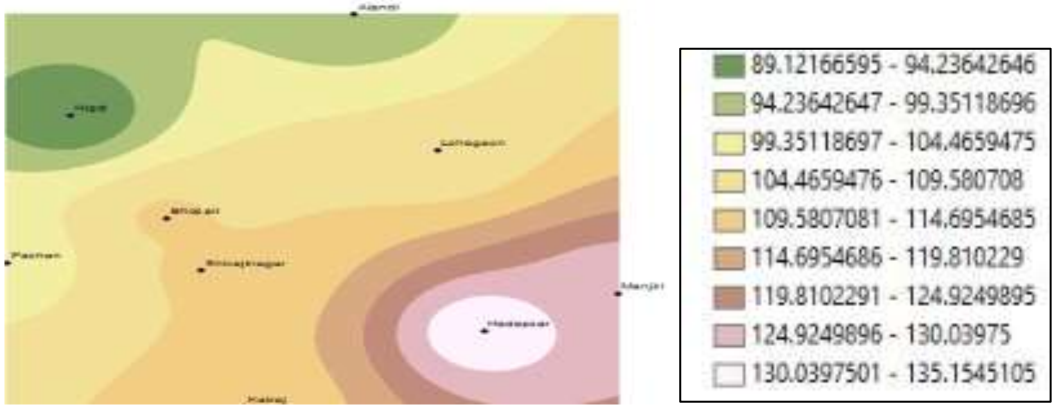


Figure 4.16 –Weekdays Spatial Interpolation of $PM_{2.5}$ at 12:00

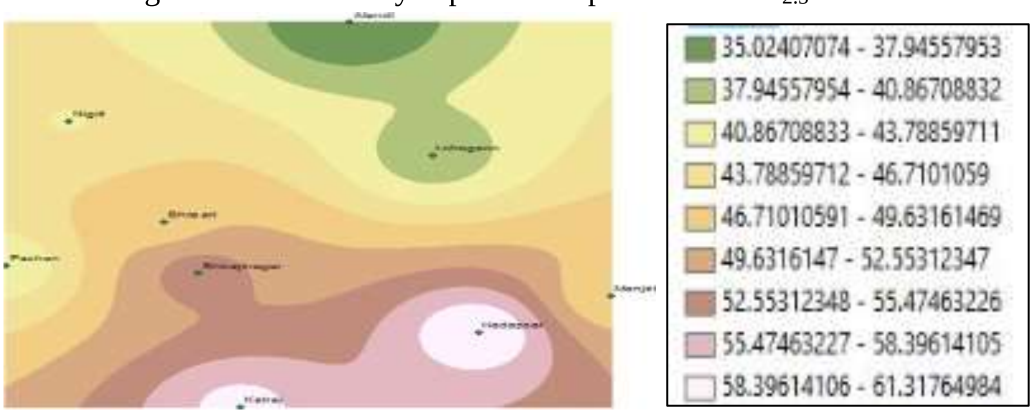


Figure 4.17 –Weekdays Spatial Interpolation of $PM_{2.5}$ at 20:00

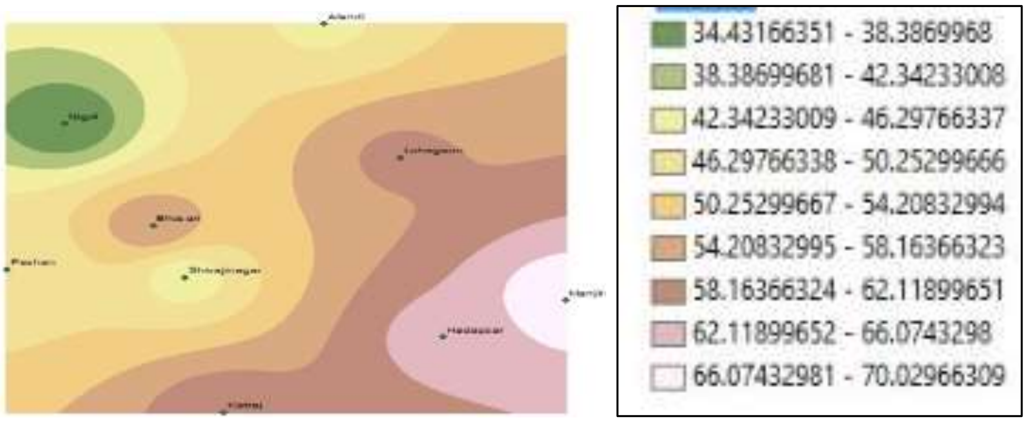


Figure 4.18 –Weekdays Spatial Interpolation of $PM_{2.5}$ at 20:00

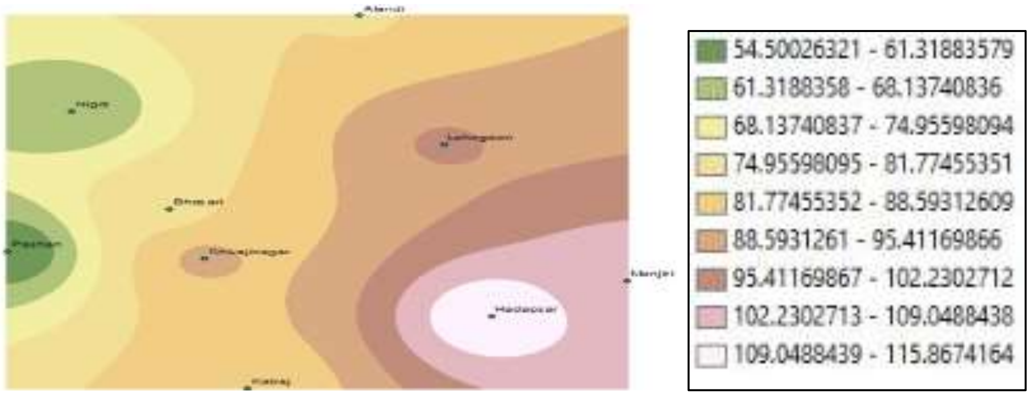


Figure 4.19 –Weekdays Spatial Interpolation of $PM_{2.5}$ at 00:00

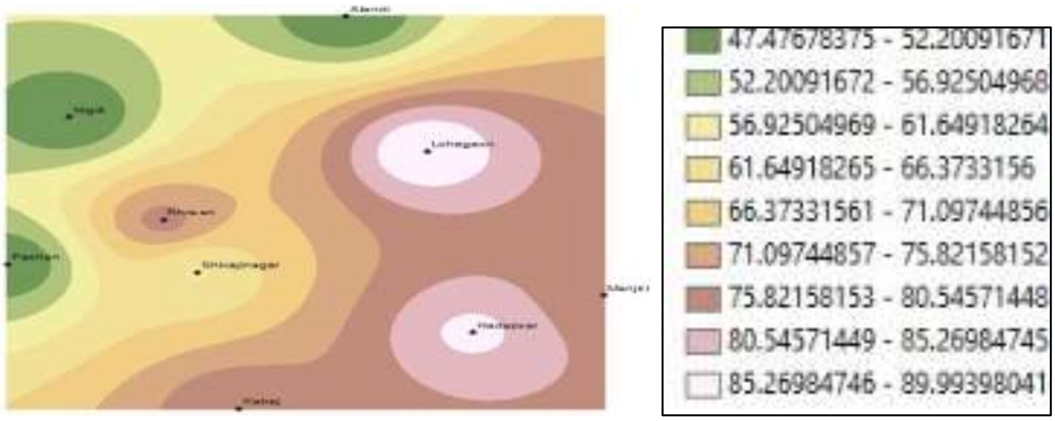


Figure 4.20 –Weekdays Spatial Interpolation of $PM_{2.5}$ at 00:00

From the Spatial Interpolation on GIS platform we can understand the highly polluted areas and relatively less polluted areas at certain time. It is found from the Air Quality Data that Weekdays have worse air quality than the weekends.

4.6 Conclusion

4.6.1 Advantage of GIS Maps representing Air Quality

Public can know the pollution data without any aid of technical persons,

1. It is real-time based system when compared to other methods.
2. It is useful for Pollution Control Board to view pollution data and to rectify or take necessary steps to control pollution.
3. It can be used to monitor industrial pollution by placing near the chimneys and through virtual control.
4. It is cost effective compared to other methods.

GIS is used to illustrate the spatial distribution of the air pollutants. correlation analysis and simple buffer analysis of GIS using the average levels of air pollutants from monitoring stations setup in the city is simple method for assessing the health effects of air pollution.

4.6.2 GIS Mapping Technique useful for City Planners

The City Planners are to utilise this user-friendly software for the Pollution mitigation and Control programs. GIS maps can also be useful for Residents at to make an assessment as according to the air quality index for that particular area especially for the residents with the respiratory disorders can select a safer place to reside. As according to the prevalence of higher pollutant levels we can determine the potential pollutant source and can regulate it after studying the GIS Spatial Interpolation Maps. A small number of air quality monitors greatly reduces the availability of appropriate mapping methods.

The state and central pollution control boards may continue to collaborate in the ongoing development and implementation of monitoring, data analysis, modelling, prediction and reporting, R&D, and health impact studies. Whenever necessary, they may continue to invite expertise from the universities, basic and biomedical research institutes, non-government organizations and private consultants. For data interpretation, modelling and prediction, GIS based methodologies may be adopted. Personal exposure estimates, which are most important for evaluation of health impact of air pollution, are almost non-existent in India. The monitoring agencies should consider this aspect. Admittedly, it is a tough proposition to implement. But someone should start it somewhere, because it is necessary.

4.6.3 Necessity of Greater number of Monitoring Stations

Ambient air pollutant concentrations are measured by air pollution monitoring networks in a number of countries around the world. These measurements are combined with mathematical models to forecast air pollutant levels over 24 to 48 hours. Both measured concentrations and predicted levels are disseminated to the public in various ways. At present, there is no accepted consensus standardization of approaches or methods, but in general, most authorities convert increasing concentrations of major air pollutants (Ozone, $PM_{2.5}$, PM_{10}, carbon monoxide, nitrogen dioxide, and sulphur dioxide) into severity bands labelled with progressive degrees of risk. There has been a rapid expansion of Pune in terms of area coverage in recent times. Therefore the number of air quality monitoring stations should be increased from the present number to keep pace with city’s growth. More stations are needed particularly in hot spots from pollution perspective where the vehicular and industrial emissions are high. Similarly, monitoring stations at areas with low background air pollution level such as in the south-western of the Pune city may be considered.

CHAPTER 5

EFFECTS OF AIR POLLUTANTS ON HUMAN HEALTH

Major Pollutants are discussed such as Particulate Matter, Nitrogen Oxide, Ozone, Sulphur di Oxide in this Chapter.

4.1 Particulate Matter

Airborne particulate matter represents a complex mixture of organic and inorganic substances. Mass and composition in urban environments tend to be divided into two principal groups: coarse particles and fine particles. However, the limit between coarse and fine particles is sometimes fixed by convention at 2.5 µm in aerodynamic diameter ($PM_{2.5}$) for measurement purposes. The smaller particles contain the secondarily formed aerosols (gas-to-particle conversion), combustion particles and recondensed organic and metal vapours. The larger particles usually contain earth crust materials and fugitive dust from roads and industries. The fine fraction contains most of the acidity (hydrogen ion) and mutagenic activity of particulate matter, although in fog some coarse acid droplets are also present. Whereas most of the mass is usually in the fine mode (particles between 100 nm and 2.5 µm), the largest number of particles is found in the very small sizes, less than 100 nm. As anticipated from the relationship of particle volume with mass, these so-called ultrafine particles often contribute only a few % to the mass, at the same time contributing to over 90% of the numbers. Particulate air pollution is a mixture of solid, liquid or solid and liquid particles suspended in the air. Atmospheric PM is a highly variable and complex mixture of particles and gases. Primary particles are emitted directly from sources, while secondary particles are formed in the atmosphere from gaseous emissions. $PM_{2.5}$ and precursor gases can be transported over long distances, allowing mixing of the two over space and time as well as mixing of urban and rural pollution. This makes it difficult to identify which sources are producing the primary particulate matter material and precursor gases.

These suspended particles vary in size, composition and origin. It is convenient to classify particles by their aerodynamic properties (a) these properties govern the transport and removal of particles from the air; (b) they also govern their deposition within the respiratory system and (c) they are associated with the chemical composition and sources of particles.

The evidence on airborne particulate matter (PM) and its public health impact is consistent in showing adverse health effects at exposures that are currently experienced by urban populations in both developed and developing countries. Sources of PM_{10} are produced by mechanical processes such as construction activities, road dust re-suspension and wind; whereas the latter originate primarily from combustion sources. the combustion of wood and other biomass fuels can be an important source of particulate air pollution, the resulting combustion particles being largely in the fine ($PM_{2.5}$) mode.

4.1.1 Fractions of Particulate Matter affects the Human Body

Along all the criteria air pollutants, particulate matter (SPM and RSPM) has emerged as the most critical pollutant in almost all urban areas of the country. Coarser fraction (> PM_{10}) of SPM concentrations are primarily irritants and may not have much relevance to direct health consequences as compared to effects of its respirable fractions (PM_{10} and $PM_{2.5}$), which can penetrate the human respiratory systems deeper. Since the year 2000, focus has shifted from SPM to PM_{10} monitoring. In view of this, the main focus of this study is on characterization and source apportionment of PM_{10}. Limited exercise on characterization and source apportionment of $PM_{2.5}$ a relatively more hazardous particulate fraction, has also been included in order to have a better understanding and correlation between these two fractions.

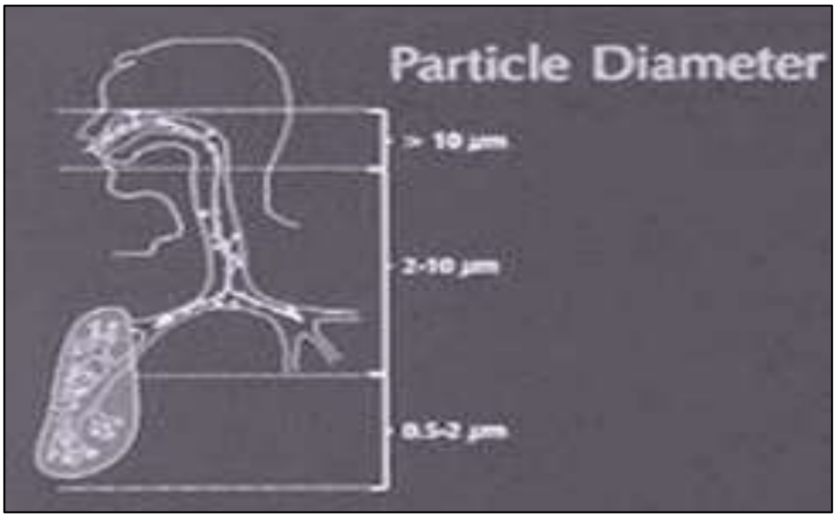


Figure 4.1 – Range Particulate Matter affects human respiratory system

Coarse particles (2.5-10 µm) deposited in upper respiratory tract and large airways. Fine particles (2.5 µm) may reach terminal bronchioles and alveoli.

4.1.2 Influence of Particle size on deposition on Lung

Particle size is the most important factor in determining where particles are deposited in the lung. Compared with large particles, fine particles can remain suspended in the atmosphere for longer periods and be transported over longer distances. Some studies suggest that fine particles have stronger respiratory effects in children than large particles. This diagram shows that particles greater than 10 micrometres rarely make it past the upper airways, whereas fine particles smaller than 2 micrometres can make it as far as the alveoli. PM_{10} particles with a diameter less than 10 micrometres (course particles). $PM_{2.5}$ particles with a diameter less than 2.5 micrometres (fine particulates) .[56] summarizes several pathways by which PM can cause damage to cells in the lung as well as to other tissues in the heart, liver, bone marrow and brain. Reducing the health effects associated with ambient PM is not a simple undertaking. It involves understanding not only the effects of PM, but also the linkages between PM emitted from sources and how that PM makes its way through the air and into the human body. Each step along the way between source and health effect is complicated and makes it difficult to link the observed effect back to the specific source or even source type. The health effects of PM are thought to be strongly associated with particle size, composition, and concentration; even though relative risk estimates indicate that the risk per unit PM mass falls within a limited range of values for these parameters.

4.1.3 Influence Mass and Composition of Particulate Matter

A combination of species and daily variations in PM mass and composition are believed to contribute to the toxicity of the particulate matter air pollution. Furthermore, measuring the relevant parameters and quantifying the health effects are extremely challenging, as numerous external factors, including meteorology and socioeconomic aspects of the human lifestyle, strongly affect human morbidity and mortality. Identifying and correcting for the effects of confounding factors remain a difficult task.

People are exposed to $PM_{2.5}$ from many sources as they go about their daily activities, spending time in their homes, at work, in recreation, and in traveling. This is further complicated by the knowledge that some individuals or segments of the population are more susceptible to PM exposures, due to factors such as respiratory habits (e.g., mouth breathing versus nose breathing), pre-existing diseases, or genetics. Given all these complications, it is interesting to note that fixed monitoring stations at a central urban site seem to provide reasonable estimates of total exposure of an individual to $PM_{2.5}$ mass and some secondary species like SO_2^{-4}. However, determining concentrations of other species such as metals and organic compounds may require measurements in each microenvironment.

4.1.4 Chemical Composition of Particulate Matter affecting the Health

The chemical composition of PM varies greatly and depends on many factors, such as combustion sources, climate, season and type of urban or industrial pollution. The major components of PM are organic compounds adsorbed onto particles, which can be volatile or semi volatile organic species (e.g., PAHs, nitro-PAHs, quinones), transition metals (iron, nickel, vanadium, copper, etc.), ions (sulphate, nitrate, acidity), reactive gases (ozone, peroxides, aldehydes), particle core of carbonaceous material (mainly from combustion processes and vehicular exhaust particles), materials of biologic origin (endotoxins, bacteria, viruses, animal and plant debris), and minerals (quartz, asbestos, soil dust). Chemical composition of PM varies according to sources and combustion factors that govern their size and chemical components [56,57]

PM pollution is considered the most important factor in urban areas, compared with gas pollutants, and several mechanisms have been proposed to explain the adverse health effects in humans, especially the cardiopulmonary system [58].

The most important pathophysiological mechanism that has been proposed to explain the association of PM exposure and occurrence of respiratory infections, lung cancer, and chronic cardiopulmonary diseases are oxidative stress through the generation of ROS. In addition, PM initiate inflammatory damage and upregulation of proinflammatory mediators (cytokines and chemokines), endotoxin effects, stimulation of capsaicin/irritant receptors, procoagulant effects, modification of cellular components, cellular mutagenicity, and DNA damage [59,60].

4.1.5 Effects of Metals within Particulate Matter (PM) on Human Health

Metals that are components of ambient air particulate matter (PM), and especially some of those that are within the fine PM (FPM) fraction, have been cited as PM components that are most likely to be toxic. The focus has often been on transition metals such as iron (Fe), vanadium (V), nickel (Ni), chromium (Cr), copper (Cu), and zinc (Zn) on the basis of their ability to generate reactive oxygen species (ROS) in biological tissues. The respiratory system is one major route whereby these chemicals and toxic agents enter the body and cause disorders, including mortality. On a global scale, millions suffer from respiratory ailments and other diseases attributed to the presence of toxic chemicals and biological agents in the air.

Suspended particulate matter (SPM) refers to the mixture of solid and liquid particles in air. In a broader sense the term applies to matter in the atmosphere classed into particles having a lower size limit of the order of 10–3 µm and an upper limit of 100 µm. SPM, a complex mixture of organic and inorganic substances, is a ubiquitous air pollutant, arising from both natural and anthropogenic sources.

According to [58], PM_{10} fraction that causes significant health impacts is dominated by particles from three sources.

- Primary fine particles from industrial and combustion sources, predominantly road traffic.
- Secondary aerosol, mostly ammonium sulphate and ammonium nitrate formed through photochemical reactions.
- Wind-blown soil and resuspended street dust present largely in coarse fraction (2.5–10 mm).

Effect of air pollution on the public health depends on composition of the particular hazardous pollutant , the level of the concentration , existing health of the receptor and period of the exposure.

4.1.6 Toxicological and Epidemiological studies Particulate Matter

Toxicological and Epidemiological studies provided evidence of a primary respiratory effect of PM exposure. Three mechanisms were put forward observed respiratory effects:

1) Lung injury/inflammation;

2) Increased airway reactivity/asthma exacerbation; and

3) Impaired lung defence mechanisms/increased susceptibility to respiratory infections

Particulate Matter is of very high health risk (as particles of smallest diameter penetrate deepest into the lungs, contribute to reduced lung function and are then transported to the organs via the bloodstream. Ambient aerosols with mass median aerodynamic diameter less than 10 µm 2.5 µm are of interest owing to their effects on human health,visibility, and climate [61,62] Additional epidemiological studies have provided more quantification of subtle health effects associated with fine PM, which is common in the contemporary urban areas and big cities in the developed countries, by better definitions and measures of air pollution exposures and health endpoints. In addition, advanced biostatistical and econometric techniques for longitudinal or cross-sectional analysis have greatly expanded the evaluation of health effects [26,32].

4.2 Ozone

Ozone is one of the most harmful gaseous air pollutants. It formed from secondary reaction but it is formed in complex photochemistry of oxides of nitrogen (NO_X) and volatile organic compounds (VOCs) in the atmosphere. Meteorological variables like wind speed should be taken into account during monitoring days. Besides, ozone levels have diurnal variation; therefore it should be measured at different times of the day to get an overall picture. As sunlight plays a vital role in the production of Ozone time of the days need to be taken into account during monitoring to get the detailed analysis of Ozone. Even for Summer it is very Important to monitor ozone levels as the solar radiations are high during the summers.

Ozone may cause significant malfunctioning of their lungs, as well as airway inflammation that would cause symptoms and alter performance by ozone .The evidence on airborne particulate matter (PM) and its public health impact is consistent in showing adverse health effects at exposures that are currently experienced by urban populations in both developed and developing countries Ozone is the most important photochemical oxidant in the troposphere. It is formed by photochemical reactions in the presence of precursor pollutants such as NOx and volatile organic compounds. In the vicinity of strong NOx emission sources, where there is an abundance of NO, O_3 is "scavenged" and as a result its concentrations are often low in busy urban centres and higher in suburban and adjacent rural areas. O_3 is also subject to long-range atmospheric transport and is therefore considered as a trans-boundary problem. As a result of its photochemical origin, O_3 displays strong seasonal and diurnal patterns, with higher concentrations in summer and in the afternoon. The correlation of O_3 with other pollutants varies by season and location. There is evidence from controlled human and animal exposure studies of the potential for O_3 to cause adverse health effects. Epidemiological studies have also addressed the effects of short and long-term exposures to O_3 and provided important results. However, the health effects of O_3 have been less studied than those of PM and thus more research is needed, especially addressing the spatial and seasonal patterns and misclassification of individual exposure in association with health outcomes.

Epidemiological and controlled human studies have shown that acute exposure to Ozone(O_3) is associated with adverse health effects that range in severity of response depending on exposure dose, other ambient co-pollutants, and individual-specific factors (e.g., age, sensitivity, tolerance). Milder effects of O_3 include eye irritation, an increase in respiratory symptoms (such as cough), small reversible decrements in pulmonary function, and a progressive decrease in tidal volume with compensatory increase in frequency (to maintain minute ventilation). More severe effects include an aggravation of pre-existing respiratory diseases (e.g., asthma) and increased medication use, airway inflammation and hyper-responsiveness, acute cellular and tissue injury, and bronchial irritation and constriction leading to wheezing and larger decrements in pulmonary function.

Studies of the acute health effects of Ozone began in the early 1960s and by the 1970s it was evident that Ozone(O_3) was an intense irritant oxidant gas. Ozone (O_3) is a highly reactive gas that results primarily from the action of sunlight on hydrocarbons and NOx emitted in fuel combustion. Since ozone can provoke both airway hyperactivity and "prime" epithelial inflammatory responses, it is a likely contributor to the overall burden of asthma [42]. Ozone irritates and inflames the respiratory system at levels frequently found across the nation during the summer months. Breathing ozone may lead to shortness of breath, chest pain; inflammation of the lung lining, wheezing and coughing, increased risk of asthma attacks, and need for medical treatment or hospitalization. Ozone may also cause premature death.

4.3 Nitrogen Dioxide

Most atmospheric NO_2 is emitted as NO, which is rapidly oxidized by ozone to NO_2. Nitrogen dioxide, in the presence of hydrocarbons and ultraviolet light, is the main source of tropospheric ozone and of nitrate aerosols, which form an important fraction of the ambient air $PM_{2.5}$ mass. The primary sources of nitrogen oxides are motor vehicles, power plants, and waste disposal systems. There is still no robust basis for setting an annual average guideline value for NO_2 through any direct toxic effect. Evidence has emerged, however, that increases the concern over health effects associated with outdoor air pollution mixtures that include NO_2. As for PM and O_3, the evidence on NO_2 and health comes from different sources of information, including observational epidemiology, controlled human exposures to pollutants and animal toxicology. The observational data are derived from studies outdoors where NO2 is one component of the complex mixture of different pollutants found in ambient air and from studies of NO_2 exposure indoors where its sources include unvented combustion appliances.

Interpretation of evidence on NO_2 exposures outdoors is complicated by the fact that in most urban locations, the nitrogen oxides that yield NO_2 are emitted primarily by motor vehicles, making it a strong indicator of vehicle emissions (including other unmeasured pollutants emitted by these sources). NO_2 (and other nitrogen oxides) is also a precursor for a number of harmful secondary air pollutants, including nitric acid, the nitrate part of secondary inorganic aerosols and photo oxidants (including ozone). The situation is also complicated by the fact that photochemical reactions take some time (depending on the composition of the atmosphere and meteorological parameters) and air can travel some distance before secondary pollutants are generated. These relationships are shown schematically in Figure 4.2.

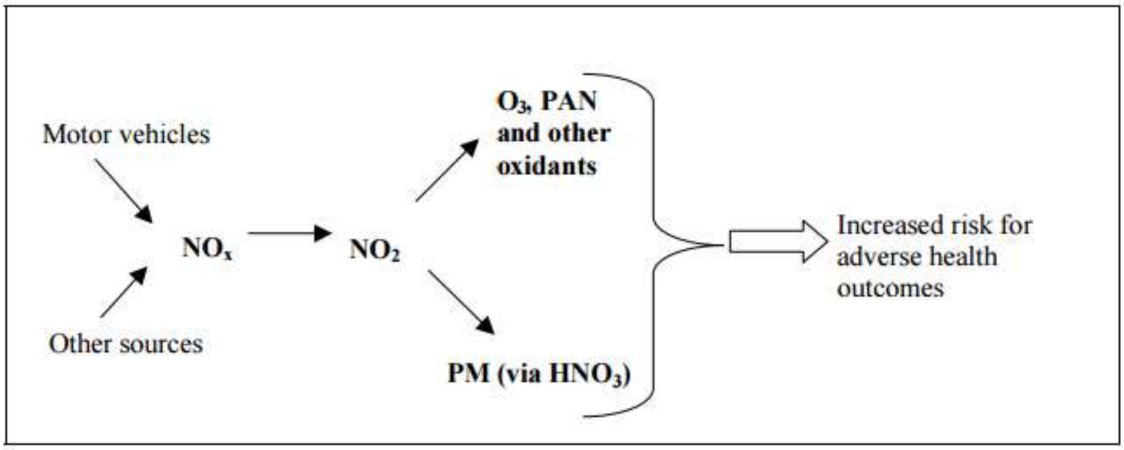


Figure 4.2 Simplified relationship of nitrogen oxides emissions with formation of NO_2 and other harmful reaction products including O_3 and PM

Nitrogen oxides emitted in the atmosphere in the oxidation process are the pollutants which destroy the stratospheric ozone, increase the UV radiation intensity, affect the global climate changes, and produce acid rains and photochemical smog. The development of nitrogen oxides in the process of fossil fuels oxidation is a very complex process affected by chemise, fuel, heat exchange and some typical flows. Nitrogen oxides represent the main polluting materials. Solid fuels consumers emit great amounts of nitrogen oxides. It can be said that the filtration of smoke gases in order to eliminate solid particles has been done for quite a long time. The fuel combustion in engines creates nitrogen monoxide (NO), which develops in high temperatures. It is thermal nitrogen monoxide (NOx). Besides this thermal reaction (of nitrogen and oxygen from the air), there develops the thermal reaction with the chemically bound nitrogen in the very fuel they originate from – NOx from fuel. The nitrogen monoxide thus formed (thermally and from the fuel) is identified exclusively as NO in the heated smoke gas.

Only after the cooling of the smoke gases and in contact with the atmosphere is it transformed into other oxides: nitrogen dioxide NO_2, nitrogen trioxide N_2O_3. It is the reason why certain data concerning NOx are unreliable if the study is not done under the determined conditions. The emitted NOx gases contain nitrogen monoxide NO the most and less the other nitrogen gases. Nitrogen dioxide and nitrogen monoxide differ in the kind and level of harmful effect. The former is a dangerous irritable poison which provokes the respiratory tract mucous membrane inflammation, lung damage and swelling. Nitrogen monoxide causes the incorrigible hemoglobulin changes, that it it blocks the hemoglobulin in blood. Due to the ultraviolet radiation and in the presence of oxygen nitrogen oxides help create ozone which leads to the formation of smog in big cities. In small quantities it does harm to photosynthesis, plant respiration.

Nitrogen oxides (NOx), a mixture of nitric oxide (NO) and nitrogen dioxide (NO_2), are produced from natural sources, motor vehicles and other fuel combustion processes. NO is colourless and odourless and is oxidised in the atmosphere to form NO_2 which is an odorous, brown, acidic, highly-corrosive gas. Nitrogen dioxide(NOx) causes a range of harmful effects on the lungs, including: increased inflammation of the airways; worsened cough and wheezing; reduced lung function; increased asthma attacks; greater likelihood of emergency department and hospital admissions; and increased susceptibility to respiratory infection, such as influenza.

4.4 Sulphur Dioxide

Sulphur dioxide (SO_2) is one of a group of highly reactive gasses known as “oxides of sulphur.” The largest sources of SO_2 emissions are from fossil fuel combustion at power plants (73%) and other industrial facilities (20%). Smaller sources of SO_2emissions include industrial processes such as extracting metal from ore, and the burning of high sulphur containing fuels by locomotives, large ships, and non-road equipment. SO_2 is linked with a number of adverse effects on the respiratory systems.

Current scientific evidence links short-term exposures to SO_2, ranging from 5 minutes to 24 hours, with an array of adverse respiratory effects including bronchoconstriction and increased asthma symptoms. These effects are particularly important for asthmatics at elevated ventilation rates (e.g., while exercising or playing.) Studies also show a connection between short-term exposure and increased visits to emergency departments and hospital admissions for respiratory illnesses, particularly in at-risk populations including children, the elderly, and asthmatics.

EPA's National Ambient Air Quality Standard for SO_2 is designed to protect against exposure to the entire group of sulphur oxides (SO_x). SO_2 is the component of greatest concern and is used as the indicator for the larger group of gaseous sulfur oxides (SO_x). Other gaseous sulphur oxides (e.g. SO_3) are found in the atmosphere at concentrations much lower than SO_2. Emissions that lead to high concentrations of SO_2 generally also lead to the formation of other SO_x. Control measures that reduce SO_2 can generally be expected to reduce people's exposures to all gaseous SO_x. This may have the important co-benefit of reducing the formation of fine sulphate particles, which pose significant public health threats. SO_x can react with other compounds in the atmosphere to form small particles. These particles penetrate deeply into sensitive parts of the lungs and can cause or worsen respiratory disease, such as emphysema and bronchitis, and can aggravate existing heart disease, leading to increased hospital admissions and premature death.

4.5 Carbon Monoxide

Carbon monoxide (CO) is a colourless, odourless gas emitted from combustion processes. Nationally and, particularly in urban areas, the majority of CO emissions to ambient air come from mobile sources. CO can cause harmful health effects by reducing oxygen delivery to the body's organs (like the heart and brain) and tissues. At extremely high levels, CO can cause death.

Mechanisms of Carbon Monoxide Toxicity Absorption and metabolism in tissue: Carbon monoxide is absorbed through the lungs and diffuses across the alveolar capillary membrane. The exchange of carbon monoxide between inhaled air and the blood is controlled by both physical (mass, transport and diffusion) and physiological (alveolar ventilation and cardiac output) mechanisms. Once absorbed, CO diffuses through the plasma, passes across the red blood cell membrane, and finally enters the red blood cell stroma where CO binds to haemoglobin forming carboxyhemoglobin (COH_b). CO can cause harmful health effects by reducing oxygen delivery to the body's organs (like the heart and brain) and tissues. At extremely high levels, CO can cause death. Exposure to CO can reduce the oxygen-carrying capacity of the blood. People with several types of heart disease already have a reduced capacity for pumping oxygenated blood to the heart, which can cause them to experience myocardial ischemia (reduced oxygen to the heart), often accompanied by chest pain (angina), when exercising or under increased stress.

4.6 Organic Compounds

Organic Compounds such as benzene, and polycyclic aromatic hydrocarbons such as benz(a) pyrene are potential cancer-causing agents present in ambient air and their main source is vehicular exhaust, which is the principle contributor of urban air pollution in India. Considering their health impact coupled with absence of a threshold level for their carcinogenicity, these two compounds should be monitored regularly in order to minimize their emissions to protect public health. Estimation of various aeroallergens including pollen and fungal spores and their relationship with asthma and other forms of bronchial allergy should be undertaken in the city at regular intervals. An important lacuna is the absence of facilities for regular monitoring of public health in relation to air pollution exposures despite the fact that protection of public health is the ultimate goal of air quality monitoring. Regular monitoring of public health may be carried out.

The concentrations of air-borne pollutants in different parts of India have been measured by various organizations but in most cases these studies were not linked to health of the exposed subjects. How air pollution affects public health and which fraction or component need to be controlled is important for reduction of air pollution in order to safeguard health of the citizens. Unfortunately, data on health effects of air pollution from Indian cities is scanty, and investigation on the health effects of chronic, long-term exposures to ambient air pollution with special reference to particulate matter is almost lacking. More epidemiological studies on health impact of air pollution in urban as well as rural India with special reference to chronic exposures may be undertaken. In this context, it is recommended that the epidemiological study may be conducted at regular intervals to detect and analyze the health effects of air pollution. The weight of this inhaled air is greater than the food we consume and the water we drink in a day. The lung volume and breathing frequencies of healthy adults at rest are 400-500 ml and 15-17 breaths per minute respectively [63]. The health impact of short-term exposure to air pollution has been the focus of much recent research, the majority of which is based on time-series studies. A time-series study uses health, pollution and meteorological data from an extended urban area. Short-term exposure to air pollution can cause and aggravate a number of respiratory conditions, including asthma, bronchitis and chronic obstructive pulmonary disease (COPD).

4.7 Observations

4.7.1 Groups most vulnerable to Air Pollution

High risk groups: Air pollution potentially affects everyone but on different time scales, and some are much more vulnerable than others. As with any health problem arising from environmental or behavioural risks there may be important interactions with an individual's genetic make-up or previous and current medical problems.

Those most sensitive to air pollution health effects include very young children(0-6 years) , elderly(above 65 years) with lifestyle risk factors for chronic disease like sedentary life-style active or passive smoking poor nutrition, especially a lack of anti-oxidant rich foods Particular disease groups or Health states have been identified as especially at-risk from chronic air pollution exposures; heart and blood vessel disease lung disease and those with other exposures which may cause or aggravate lung disease

4.7.2 Asthmatic Response to Outdoor air pollutants

Multi-pollutant regression analyses indicated that SO_2 risk estimates for asthma outcomes were not sensitive to the inclusion of co-pollutants, including PM, NO_2, O_3 and CO, and concluded that the observed health associations for SO_2 might be attributed partly to co-pollutants, with a focus on PM and NO_2 as these pollutants tend to be moderately to highly correlated with SO_2 and have known respiratory health effects [8]. The review also reported that there was moderate evidence that long-term exposure to a NO_2 level below the World Health Organization recommended air quality annual mean guideline of $40 \mu g/m^3$ was associated with adverse health effects including asthma outcomes

Oxidative stress and both local and systemic inflammation are suggested as main mechanisms following the inhalation of these pollutants .A first step may be the release of reactive oxygen species of lung cells (e.g. through contact with inhaled particles where toxic substances such as metals are adsorbed). Particulate matter of various sizes, as well as highly oxidative gases (e.g. O_3 or NOx) have been shown to induce local pulmonary reactions related to oxidative stress [64].

The respiratory tract is the portal of entry of air pollutants, and thus the lung is the first affected organ. The range of respiratory diseases due to air pollution exposure is wide. Studies on the health effects of air pollution distinguish between acute and chronic effects.

The acute effects of pollution may be expressed within hours or days of exposure, but other health effects of air pollution result from long-term exposures leading to chronic pathologies. While the acute and chronic effects of air pollution are partly interrelated, the distinction is important when planning and interpreting epidemiological studies and for policymaking.

It has been observed that the characteristics air composition of air in typical Indian city has exceedingly high amount of SPM and RSPM. People with asthma have more sensitive airways and their lungs respond more to the effects of air pollutants such as particles, sulphur dioxide, nitrogen oxides and ozone. Outdoor pollutants not especially associated with asthma include carbon monoxide and lead. Carbon monoxide is more likely to affect people with heart disease than people with asthma.

The most common categories of people at increased risk are the people who have acute respiratory illnesses such as asthma, chronic obstructive pulmonary disease (COPD), which includes chronic bronchitis and emphysema or lung cancer. The peoples with existing cardiovascular conditions such as angina, previous heart attack, congestive heart failure or heart rhythm problems are sensitive to air pollution. People with diabetes are also more sensitive to air pollution because they are more likely to have cardiovascular disease. People participating in sports or strenuous works outdoors breathe more deeply and rapidly allowing more air pollutants to enter the lungs. On days when air pollution levels are significantly elevated, even people not in the above groups may develop symptoms of respiratory problems. People who are otherwise healthy may have the symptoms like eye irritation, increased mucus production in the nose or throat, coughing, difficulty in breathing especially during exercise.

4.7.3 Causes leading to Asthma

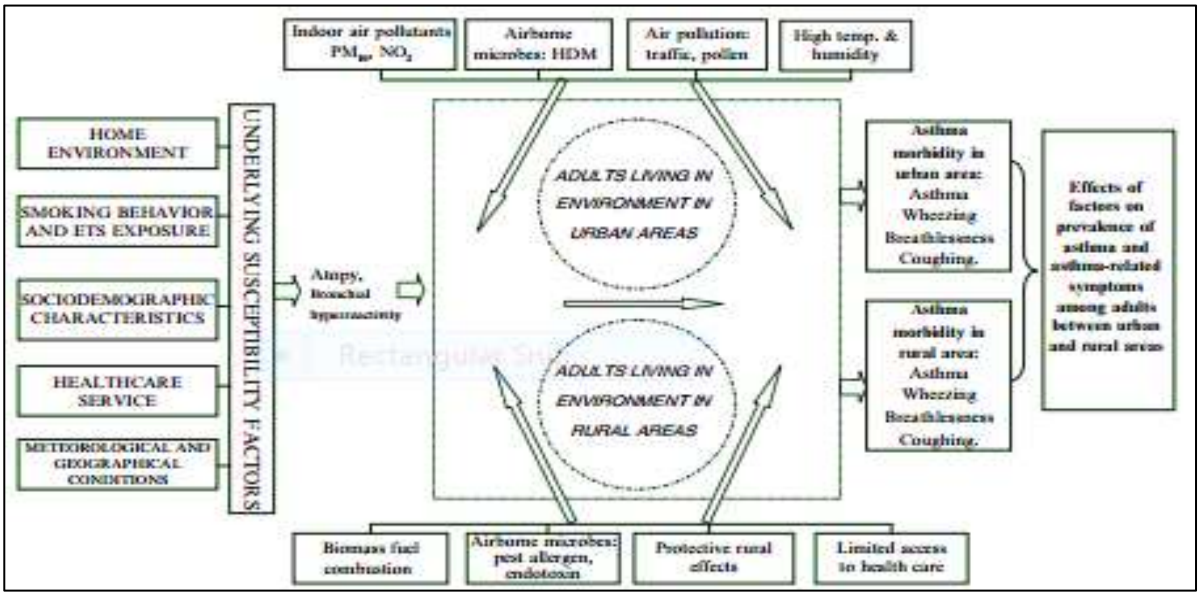


Figure 4.3 Diagram indicating exposure pathway leading to Asthma in Urban and Rural areas

In Figure 4.3, we present a diagram of our understanding of the human exposure pathways and potential factors that affect human asthma susceptibility between urban and rural areas. In this model, different environmental urban-based exposures (e.g., particulate or gaseous air pollutants from vehicular traffic, and industry), and similar ones in rural areas (e.g., indoor pollution from biomass fuel combustion, and keeping or herding animals) are known to potentially affect susceptible adult hosts. Such exposures may produce airway inflammation and obstruction. However, there are disparities between urban and rural areas in the prevalence of asthma and asthma-related symptoms. Susceptibility factors are specific to urban and rural areas, and these differences potentially influence the incidence of asthma between the two areas. Factors that may be important in susceptibility to asthma include socio-demographic characteristics, type of home environment, availability of healthcare services, meteorological or geographical differences, and degree of urbanization. Furthermore, factors like atopy and specific genetic background of exposed persons influence host susceptibility to environmental stimuli.

4.7.4 Effects on Children Health

Children, in particular, have greater exposure to air pollution because they breathe in more air per kilogram of body weight than adults do and they spend more time outside being active outdoors. Their elevated metabolic rate and young defence systems make them more susceptible to air pollution. Children with asthma or other respiratory diseases are more likely to be affected. Air pollution can trigger asthmatic attack and aggravate symptoms of respiratory ailments like coughing and throat irritation even in healthy children. The elderly people also are more likely to be affected by air pollution, due to generally weaker lungs, heart and defence systems, or undiagnosed respiratory or cardiovascular health conditions.

Several cohorts recruited during elementary or middle school and followed up into adulthood confirm that ambient air pollution jeopardises the development of children's lungs, resulting in lower lung function volumes and flows at age 18. The finding of a unique Swiss birth cohort study indeed indicated that exposure to ambient air pollution during pregnancy leads to possibly prime adverse developments of the lung Compared with adults, children have poor defences against PM and gaseous air pollutants, have a differential ability to metabolise and detoxify environmental agents and have an airway epithelium that is more permeable to inhaled air pollutants [32].

Children have a greater level of physical activity than adults (an average physical activity duration of 124 versus 21 min per day) [33], hence the intake of air into the lungs is much greater than adults per day. Children spend more time outdoors than adults, particularly in the summer and in the late afternoon. Some of that time is spent in activities that increase ventilation rates. Greater intake of air means greater amounts of ambient air pollutants will enter into the lungs. During exercise, there is a 5-times greater deposition of particles into the lungs than during rest. Per bodyweight, the volume of air passing through the lungs of a resting infant or child is twice that of a resting adult under the same conditions, and therefore twice as much (per bodyweight) of any chemical in the atmosphere could reach the lungs of an infant [34,35].One reason for the increased susceptibility of children to the effects of air pollution is their increased time spent outdoors running, playing and participating in sports that also necessitate breathing at higher ventilatory rates (i.e., increased pollutant dose)

4.8 Results

4.8.1 Summary of Pollutants their Sources and Health Effect

Fine particles deposit in distal airways: Increased acute respiratory morbidity (pneumonia, asthma) Increased mortality (from all causes) Decreased lung growth and function

Sr.No	Pollutant	Sources	Health effects
1	Particulate Matter	Vehicular Exhaust , fuel burning , constructions	↑infant respiratory mortality ↓lung function ↓lung growth ↑symptoms in asthmatics
2	Ozone	Nitrogen Oxide and volatile organic compounds secondary reaction with in presence of sunlight	↓lung growth ↑asthma exacerbations ↑asthma hospitalisation
3	Nitrogen dioxide	Fertilizer Industry, atmospheric reactions.	↑ symptoms in asthmatics ↓ lung growth
4	Carbon mono-oxide	Formed when carbon-containing fuel is not burned completely ,motor vehicles	↑ asthma hospitalisation ↑lower respiratory tract disease
5	Sulphur dioxide	Industrial sites such as smelters ,paper mills, power plants and steel smelting	↑ asthma hospitalisation ↑lower respiratory tract disease

Table 4.1 Pollutant their Sources and their related Health Effects

4.8.2 Measures to be taken to avoid the harmful effect of Air Pollution

Air Pollution is Harmful to Health following Measure shall be taken to avoid its Harmful Effects

4.8.2.1 Staying indoors

Personal exposure to ambient air pollutants occurs in both indoor and outdoor environments, and the levels of exposure depend on the fractions of time an individual spends in various indoor and outdoor environments, as well as the concentrations of outdoor-source air pollutants in those indoor and outdoor environments. In the developed world, people spend about 90% of their daily time indoors on average, with about 70% of their daily time in residential homes [40]. There is a lack of information on personal activity patterns in the developing world. Although ambient air pollutants such as particulate matter, ozone, and other gases infiltrate indoors from outdoors, concentrations are generally lower indoors compared to outdoors, and spending time indoors generally reduces exposure to ambient air pollutants. Indeed, environmental protection agencies in a number of countries advise members of the public to remain indoors as part of guidance to reduce exposure and thus acute health risk on high air pollution days [41].

4.8.2.2 Cleaning Indoor air

Portable or central air cleaning systems can reduce concentrations of indoor air pollutants, of either outdoor or indoor origin .Indoor air quality study to characterize particle removal efficiencies of several types of central, in-duct air filters/cleaners[36]. [37] modelled the health benefits of using a whole house in-duct air cleaner .The indoor-outdoor ratio of $PM_{2.5}$ will decrease from 0.57 with natural ventilation (passive air exchange through windows and other openings), to 0.35 with conventional in-duct filtration, to 0.1 with HEPA (high efficiency particle air) in-duct filtration.

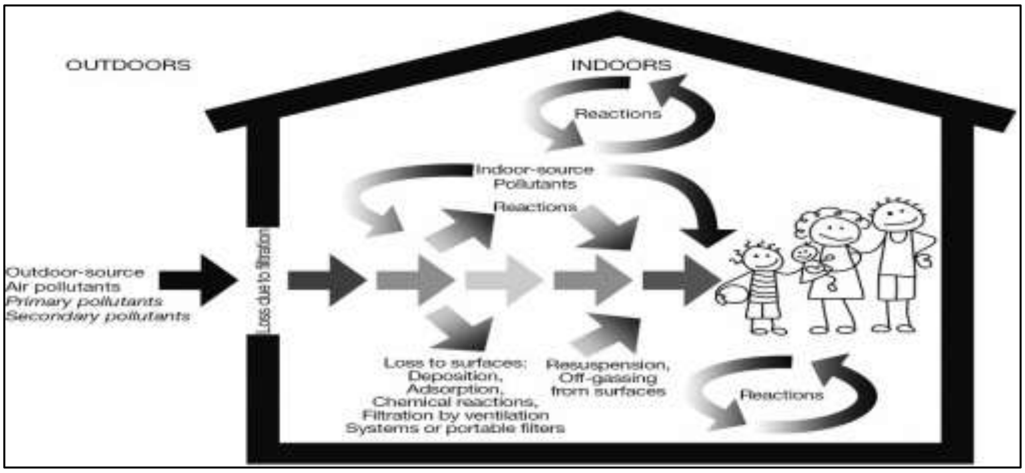


Figure 4.4 – Reactivity of Indoor Air Pollutants

4.8.2.3 Reducing the Effective Inhaled Dose of Air Pollution

In addition to staying indoors, with or without further efforts to reduce indoor pollutant levels, reducing exertion can reduce the concentration of air pollutants that are inhaled and can modify the fraction of pollutant deposited or absorbed in different regions of the respiratory tract. Compared to the mouth, the nose is a more effective filter for preventing particles and water-soluble gases and vapours from reaching the lung. Thus, breathing through the mouth at higher levels of exertion further increases the dose of pollutants that reach the lower respiratory. Another study showed that children 6-10 years old had less nasal deposition of fine particles during light exercise compared to adults, suggesting that limiting exertion in children may be especially important for reducing their exposure to PM [39].

4.8.2.4 Avoiding outdoor activity when air pollutant levels are higher

Ambient air pollution levels vary seasonally, day-to-day, and by time-of-day .Levels of air pollutants also vary in different microenvironments, such as outdoors in variable proximity to sources, at home, at workplaces, in schools, in vehicles, etc. Individuals can know when air pollution levels are likely to be elevated either by sensing poor air quality (odour, irritation, symptoms), having knowledge of conditions that tend to lead to higher air pollutant levels in their area, or via public communications based on measured or predicted levels at air monitoring stations. In order to most effectively adjust behaviour to reduce exposure and risk, individuals must be able to anticipate when and where air pollutant levels are likely to be elevated above levels thought to confer increased risk.

4.8.2.5 Reducing Exposure in Microenvironments near Sources

Air pollutant levels in specific microenvironments are highly variable and direct measurements or estimates of these levels are rarely available to aid individuals in making decisions about reducing exposure, but some generalizations about expected relative levels of air pollutants under different types of conditions in particular types of microenvironments can be useful. For example, traffic-related air pollution, may present increased risk of adverse health effects to broad populations in many urban areas of the world. Traffic-related pollutants consist of particles and gases emitted from internal combustion engines, their reaction products, tire and vehicle wear, and resuspended road dust.

Concentrations of these pollutants decline in steep gradients with distance from roadways, but large urban populations living and/or working in proximity to roadways, as well as commuters on roadways, are among those most likely to be exposed [42]. Traffic-related air pollutants have become relatively more important in areas of the world where increased industrial air pollution controls have reduced the contribution of stationary sources to total air pollution emissions.

4.8.2.6 Personal Protective Equipment—Respirators

The ability of a respirator to remove contaminants from inhaled air depends on the contaminant, type of filter or adsorbent material, respirator type and conditions of use. Although, relatively inexpensive respirators with filter material for particulate matter are widely available, no single absorbent, or available combination of adsorbents, can efficiently remove the various gas phase air pollutants that may be encountered. Gaseous pollutants can be removed based on their physicochemical properties, such as reactivity, molecular weight, and volatility. Therefore, the removal mechanism for different gaseous pollutant can be quite different, i.e., chemical reaction *vs.* adsorption; and a particular adsorbent is only suitable for removal one or a groups of pollutants with similar physicochemical properties. In general, assuming that the filter or adsorbent material is appropriate for the type of air pollutant, the efficiency of air pollutant removal by tight-fitting negative pressure respirators depends largely on the quality of the individual's face seal.

4.8.2.7 Antioxidants in the Diet to develop immunity to Pollution

Supplementation with antioxidants may therefore strengthen defence mechanisms and reduce the harmful effects of air pollution. Supplementation with vitamin C and vitamin A, especially in high doses, has shown some beneficial effects on small airway function in asthmatics exposed to O_3 who inherently synthesise low levels of glutathione. The results of animal studies suggest that supplementation with vitamin C and vitamin E modulates the pulmonary response to exposure to photo-oxidants, such as O_3 or NO_2 , and that vitamin C, uric acid and glutathione located in the respiratory tract lining fluid are consumed on exposure to O_3 and NO_2 Reduce susceptibility to the harmful effects of air pollutants intake Antioxidant supplementation .Green leafy vegetables, certain fruits are best Anti-oxidants available to intake in our diet. The harmful effects of ambient air pollutants become pronounced when the antioxidant defence mechanism becomes weak.

4.8.2.8 Public Education and Awareness on a Community Level

Mass awareness campaigns involving local bodies, voluntary organizations, students, trade unions and others may be initiated educating people about the health impact of air pollution. Moreover, air quality management and air pollution mitigation measures taken up by the government at the state or central level may be widely promoted through educational and information programmes. Environmental Health subject may be introduced in medical education syllabus in India. Vehicular Pollution is a significant contributor to Air Pollution in the city .Sustainable transportation for fast growing cities to meet the demands of huge population like Metro. People should be advised to maintain their vehicles properly. Limitation on the age of Vehicle allowed to ply shall be revised .At the same time People shall be encouraged to walk or use bicycles for traveling short distances, and to share vehicles for long distances.

4.8.2.9 Avoiding Exercise outdoors

The benefits of physical activity may be especially great for individuals who are also more sensitive to air pollution, such as those with heart and respiratory disease. On the other hand, the balance will tip more towards limiting activity as air pollution concentrations reach higher levels, on days with particularly poor air quality, or in areas with chronically elevated levels of air pollution. Encouraging individuals to exercise at locations and times when air pollutant levels are lower may help to preserve the benefits of exercise, while minimizing the health risks from exposure to air pollution.

Exposure to fine particles has been shown to increase allergen sensitisation, increase the risk of worsening asthma and decrease lung function. Lung growth, as measured by lung function, seems to be adversely affected in children exposed to various oxidant air pollutants. Oxidative stress is the main underlying mechanism responsible for the harmful effects of air pollutants and preliminary studies have indicated that antioxidant supplementation can offer some protection. Air pollution induces pathophysiological damage to the developing lung in children and adolescents.

CHAPTER 5
CORRELATION OF PULMONARY LUNG FUNCTION TEST AND AIR QUALITY

5.1 Spirometry

Spirometry is the most basic level of the pulmonary function tests (PFTs) it involves measuring of breath , measuring lung function, measurement of the volume in Litres and/or flow litres/second of air which is inhaled and exhaled. Spirometry is an important tool used for generating pneumotachographs, which are helpful in assessing conditions such as asthma, pulmonary fibrosis, cystic fibrosis, and COPD. Spirometry is an uncomplicated procedure that can easily be incorporated by primary care physicians into routine physical examinations. Especially now that simple hand held spirometers suitable for all offices are available. Abnormal Spirometric patterns can alert physicians to patients' additional risk of developing chronic lung disease and to the need for inrementions that prevent or morbidity and mortality Spirometry also is an important tool for monitoring patients' response to therapy in a number of disorders (eg. asthma).

5.1.1 Spirometry checks Ventilation function of the body

Ventilation is the movement of air between the environment and the lungs via inhalation and exhalation. Thus, for organisms with lungs, it is synonymous with breathing. Ventilation usually happens in a rhythmic pattern, and the frequency of that pattern is called the ventilation rate (or, by long-standing convention, the respiratory rate, even though in precise usage ventilation is a hyponym, not a synonym, of respiration). Spirometry requires maximal effort from the patient and it takes time to perform quality Spirometry. It is essential the procedure is carefully and clearly explained and to actively coach, coax, and motivate the patient to perform maximally. The volume and flow parameters measured are defined in the terms of maximal effort and maximal exhaled volume. The performance of Spirometry while seated upright in a chair with both feet flat on the floor is the preferred method as this is the most stable position should the patient experience dizziness during the test.

5.1.1.1 Forced Vital Capacity (FVC)

FVC Forced vital capacity: the determination of the vital capacity from a maximally forced expiratory effort. FVC is the maximal volume of air exhaled with maximally forced effort from a maximal inspiration, i.e. vital capacity performed with a maximally forced expiratory effort, expressed in litres at body temperature and ambient pressure saturated with water vapour. To perform the FVC manoeuvre, the patient must first breathe in deeply to his full extent. The patient then places the transducer to the mouth and expels the air in their lungs as quickly as possible. Once all the air in the lungs has been expelled, the patient must breathe in as quickly as possible, still with the transducer to the mouth, until the lungs are full.

5.1.1.2 FEV_1/FVC ratio (FEV_1%)

FEV_1/FVC (FEV_1%) is the ratio of FEV_1 to FVC. FEV_1 Volume that has been exhaled at the end of the first second of forced Expiration. Unhealthy adults this should be approximately 75–80% .In obstructive diseases (asthma, COPD, chronic bronchitis, emphysema) FEV_1 is diminished because of increased airway resistance to expiratory flow; the FVC may be decreased as well, due to the premature closure of airway in expiration, just not in the same proportion as FEV_1 (for instance, both FEV_1 and FVC are reduced, but the former is more affected because of the increased airway resistance). This generates a reduced value (<80%, often ~45%). In restrictive diseases (such as pulmonary fibrosis) the FEV_1 and FVC are both reduced proportionally and the value may be normal or even increased as a result of decreased lung compliance. A derived value of FEV_1% is FEV_1% predicted, which is defined as FEV_1% of the patient divided by the average FEV_1% in the population for any person of similar age, sex and body composition. The most important aspects of Spirometry are the forced vital capacity (FVC), which is the volume delivered during an expiration made as forcefully and completely as possible starting from full inspiration, and the forced expiratory volume (FEV) in one second, which is the volume delivered in the first second of an FVC manoeuvre. Other Spirometric variables derived from the FVC manoeuvre are also addressed.

Table 5.1 – Lung disease and Spirometry results

Sr.No	Interpretation	FVC	FEV1	FEV_1/FVC %
1	Normal Spirometry	Normal	Normal	Normal
2	Airway Obstruction	Low or Normal	Low	Low
3	Lung Restriction	Low	Low	Normal
4	Combination of obstruction And restriction	Low	Low	Low

Table 5.2– Stage of obstructive disease as per FEV_1/FVC

Sr.No	FEV_1/FVC	Stage of Obstructive Defect
1	> 80%	Minimal Obstructive Defect
2	65 - 80%	Mild Obstructive Defect
3	50 - 65%	Moderate Obstructive Defect
4	< 50%	Severe Obstructive Defect

5.1.1 The Parameters which affects the Lung Capacity

1. Gender - Males have larger capacity than Females
2. Body Mass - larger Mass = larger capacity
3. Muscle Mass - larger mass = larger capacity v Aerobic Fitness - greater fitness = breathing large breaths on a frequent basis = larger capacity
4. Height –Taller person have greater capacity
5. Diseases of the respiratory System - Asthma, bronchitis, colds, etc - narrower airways = less air taken in during inhalation = lungs don't stretch as much Emphysema - air sacs become brittle and break so there are less air sacs to hold air
6. Elevation where one resides - at higher elevations there is less oxygen, so at first, one has to breathe faster and deeper to get enough oxygen, and eventually, after several months, the lungs will stretch and the lung capacity will increase.

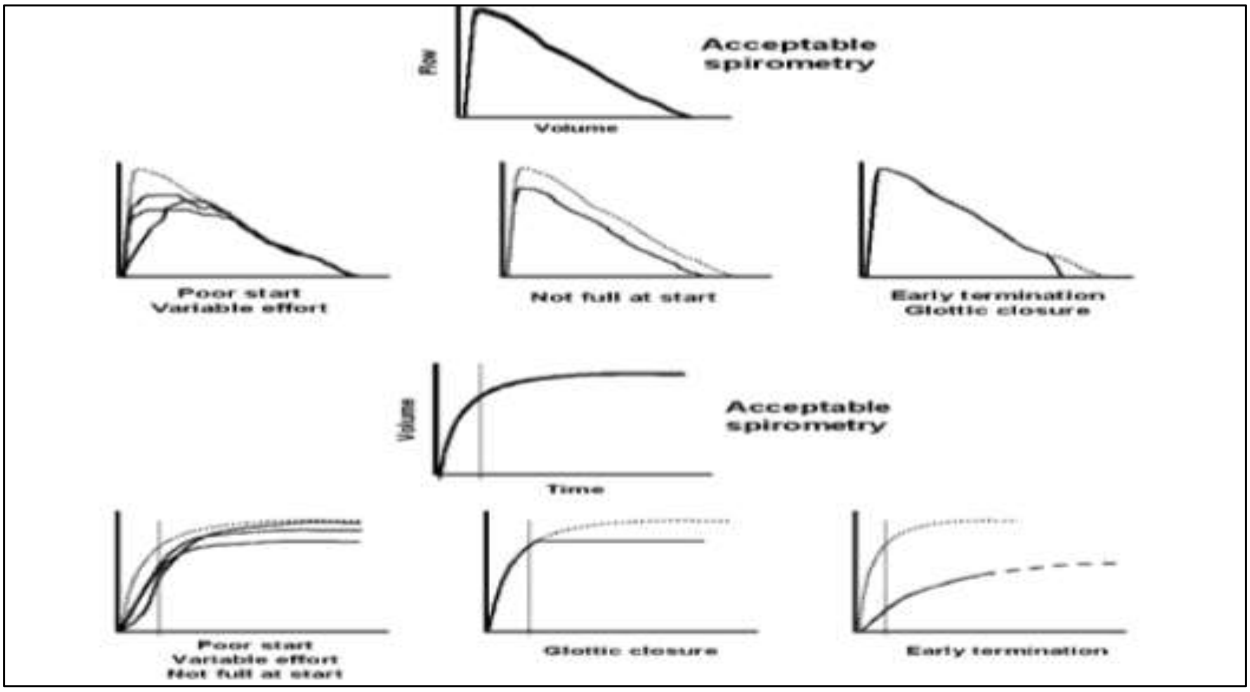


Figure 5.1 Pneumotachographs for Acceptable Spirometry

5.2 Material and Methodology

Helios 401 is a spirometer which is used in conjunction with a Windows based computer. It is used to determine the dynamic lung function by measuring the Forced Vital Capacity (FVC), Slow Vital Capacity (SVC) and the Maximum Ventilatory Volume (MVV). It has a hand piece which houses a turbine transducer. This hand piece is connected to a computer through a USB interface cable. The software given along with the system is used to record Spirometry manoeuvres and to suggest a diagnosis. The computer monitor is used to display the Spirometry parameters, the device parameters, information messages and user guide messages.

5.2.1 The key steps are to instruct the patient during Spirometry:

1. Breathe in fully ensure the lungs are completely filled with air
2. Seal the lips and teeth tightly around the mouthpiece and then immediately.
3. BLAST the air our as fast and as long as possible until the lungs are completely empty (10 seconds is optimal), and then.
4. Breathe in fully again without removing the mouthpiece from the patient's mouth
5. Repeat the test until three acceptable and reproducible results/tests are obtained (up to a suggested maximum of 8 efforts)
6. The highest FEV_1 and FVC should be reported (along with other tests measurements dictated by the ordering physician), even if these are from separate blows. But must be from the same overall series of tests on the same day.

5.2.2 Acceptable Results for Spirometry

Acceptable results are those that were initiated at full lung inflation, and with maximum expiratory effort (without hesitation at the start, no pauses, or coughing throughout the blowing phase) until no more air can be expired from the lungs. The results are reproducible if there is less than 200ml variation in the FEV_1 and FVC between the two best blows.

A spirometer that allows you to see the graph of the flow-volume loop curve in real-time and provides alert messages about test quality and patient performance makes it much easier to determine the acceptability of each test. It is preferable to have both a flow-volume loop and volume-time graphic so that the acceptability of the results can be easily judged.

5.2.3 Common Causes of Poor Quality Spirometry

- Sub-maximal effort (due to poor coaching, full bladder or full stomach)
- Inability to fully inflate the lungs prior to performing the forced exhalation
- Incomplete expiration (removing mouth from mouthpiece, coughing, etc.)
- Hesitation at the start of expiration
- Air Leaks between mouthpiece and lips , Nose-clip not used.
- Poorly calibrated/maintained spirometer
- Coughing
- Obstruction of mouthpiece by the tongue or teeth
- Vocalization during the exhalation
- Poor posture (slouching or leaning forward)

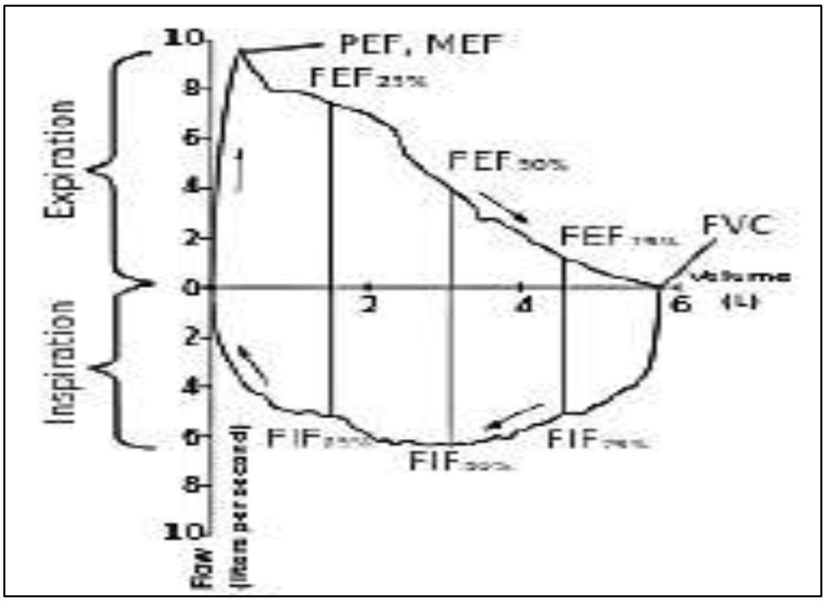


Figure 5.2 - Expiration and Inspiration Flow loop

Figure 5.2 shows Flow Volume loop showing successful FVC manoeuvre. Positive values represent expiration, negative values represent inspiration. At the start of the test both flow and volume are equal to zero (representing the volume in the spirometer rather than the lung). The trace moves clockwise for expiration followed by inspiration. After the starting point the curve rapidly mounts to a peak (the peak expiratory flow).

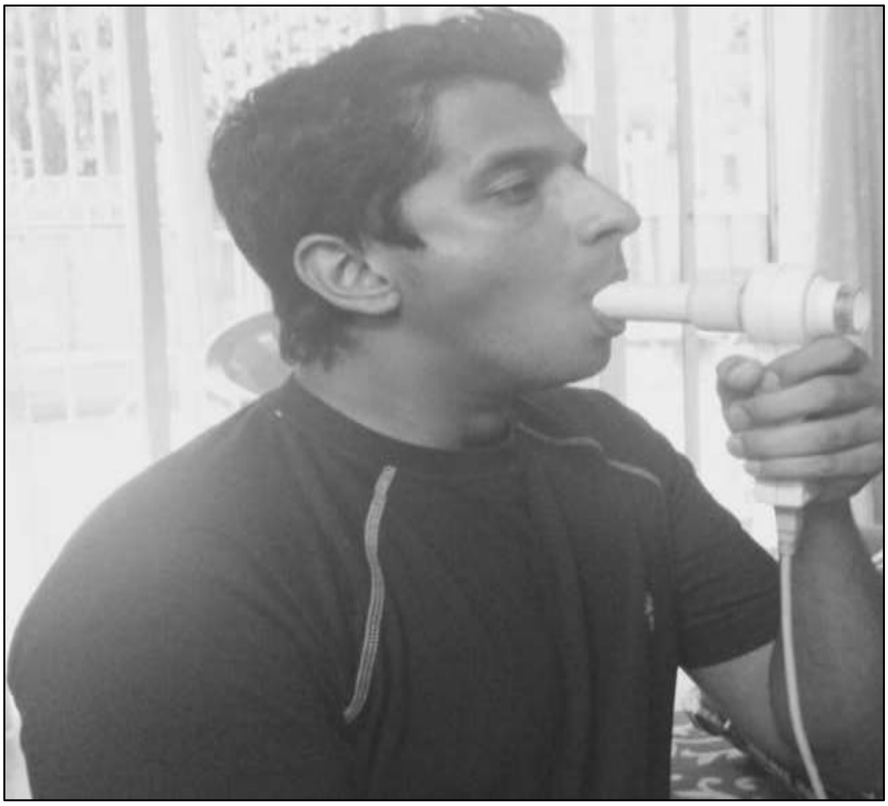


Figure 5.3 – Subject performing Spirometry Test

Observations in RMS Helios Spirometer F (Litres/Second) vs V (Litres) in the software

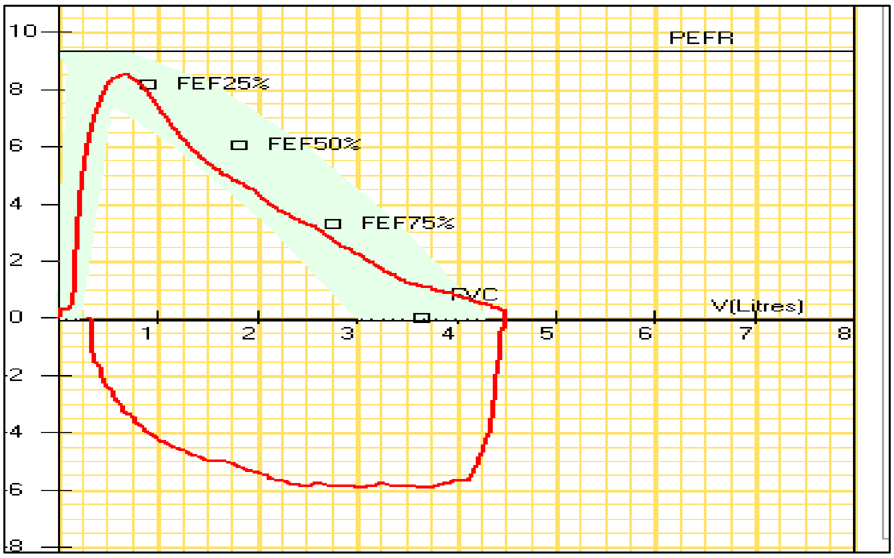


Figure 5.4 - Pneumotachographs for Normal Subject

Important Observed Spirometry Results of Diseased subjects are given below

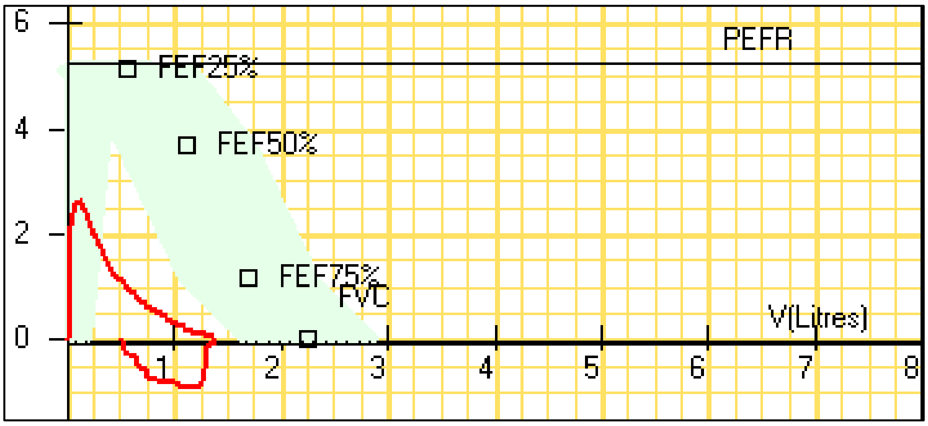


Figure 5.5 –Pneumotachographs w-loop volume curve of normal subject with end expiratory curvilinearity due to ageing

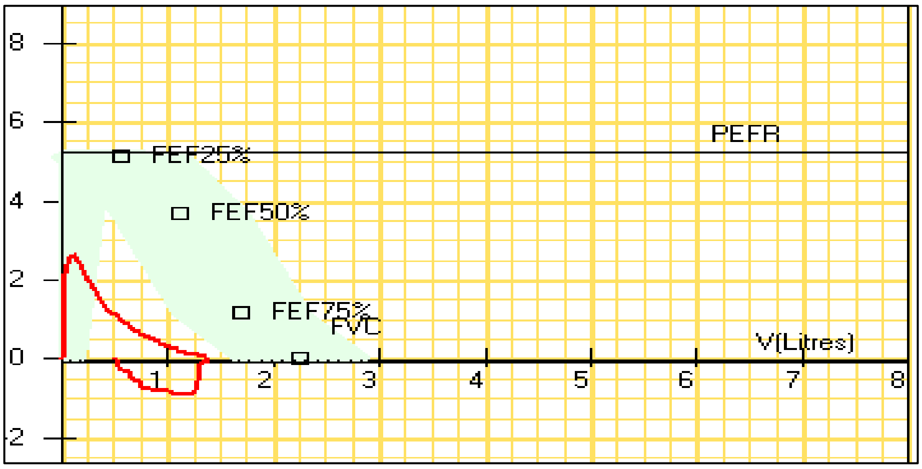


Figure. 5.6 - Moderate Airflow limitation in a subject due to Asthma

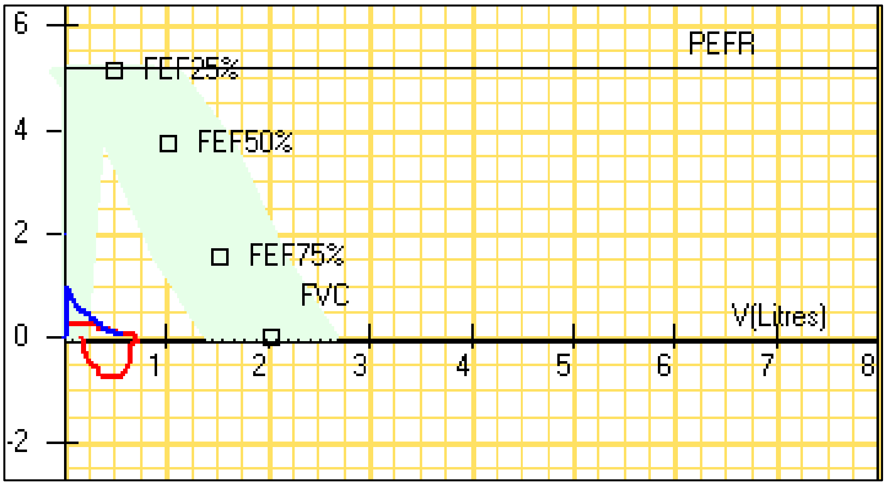


Figure 5.7- Pneumotachographs Severe Airflow limitation in a subject with chronic pulmonary disease

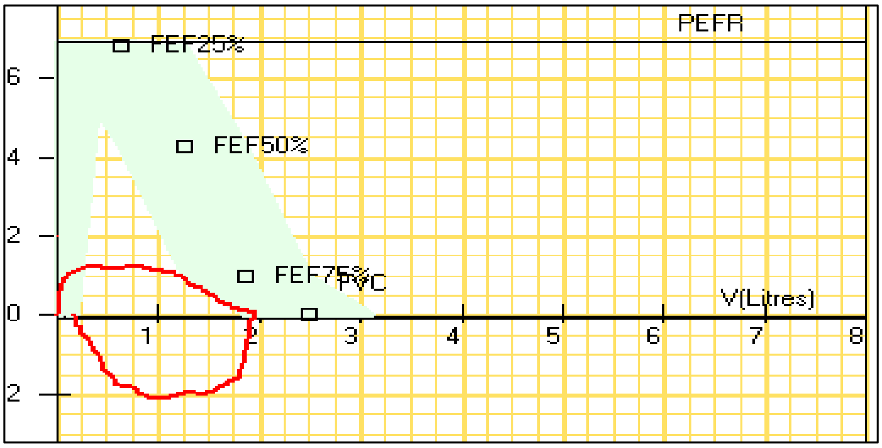


Figure 5.8- Variable intra-thoracic upper airway obstruction

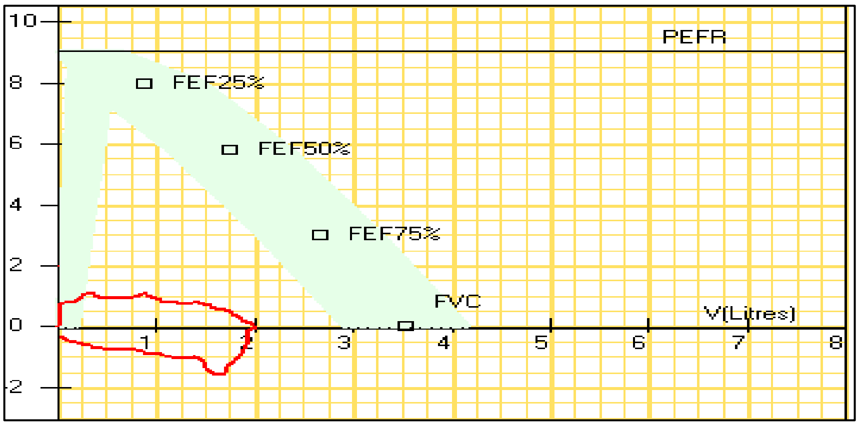
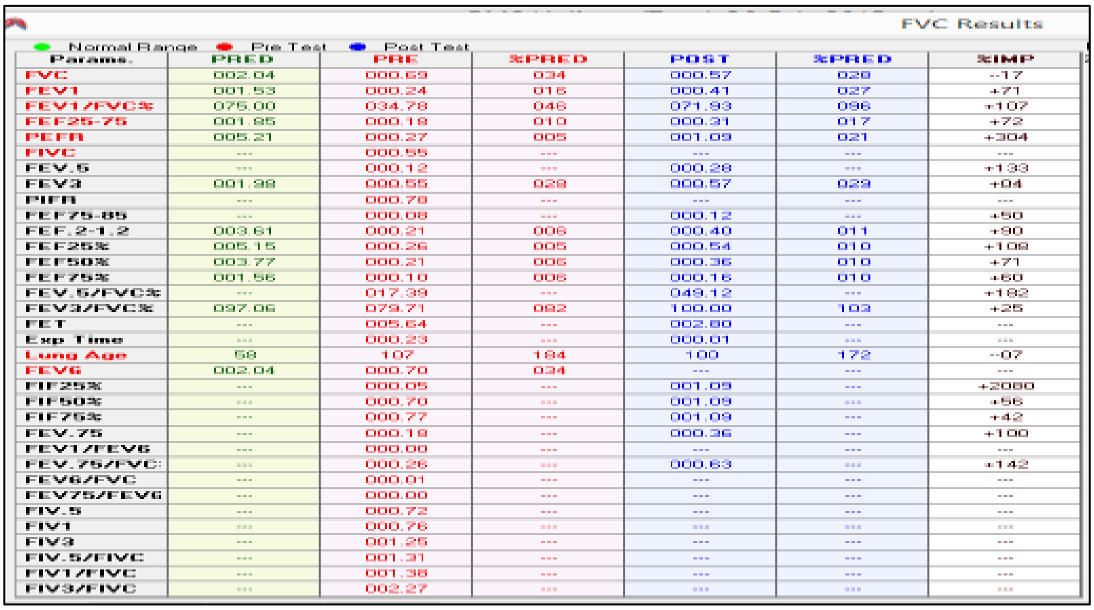


Figure 5.9 – Pneumotachographs of fixed upper airway obstruction shown by three manoeuvres

Using RMS Spirometer 15 Asthmatic And 15 Non-Asthmatic Patients are tested.



FVC Results

Normal Range Pre Test Post Test

Params.	PRED	PRE	%PRED	POST	%PRED	%IMP
FVC	002.04	000.69	034	000.57	028	--17
FEV1	001.53	000.24	016	000.41	027	+71
FEV1/FVC%	075.00	034.78	046	071.93	096	+107
FEF25-75	001.85	000.18	010	000.31	017	+72
PEFR	005.21	000.27	005	001.09	021	+304
FIVC	---	000.55	---	---	---	---
FEV.5	---	000.12	---	000.28	---	+133
FEV3	001.98	000.55	028	000.57	029	+04
PIFR	---	000.78	---	---	---	---
FEF75-85	---	000.08	---	000.12	---	+50
FEF.2-1.2	003.61	000.21	006	000.40	011	+90
FEF25%	005.15	000.26	005	000.54	010	+108
FEF50%	003.77	000.21	006	000.36	010	+71
FEF75%	001.56	000.10	006	000.16	010	+60
FEV.5/FVC%	---	017.39	---	049.12	---	+182
FEV3/FVC%	097.06	079.71	082	100.00	103	+25
FET	---	005.64	---	002.80	---	---
Exp Time	---	000.23	---	000.01	---	---
Lung Age	58	107	184	100	172	--07
FEV6	002.04	000.70	034	---	---	---
FIF25%	---	000.05	---	001.09	---	+2080
FIF50%	---	000.70	---	001.09	---	+56
FIF75%	---	000.77	---	001.09	---	+42
FEV.75	---	000.18	---	000.36	---	+100
FEV1/FEV6	---	000.00	---	---	---	---
FEV.75/FVC:	---	000.26	---	000.63	---	+142
FEV6/FVC	---	000.01	---	---	---	---
FEV75/FEV6	---	000.00	---	---	---	---
FIV.5	---	000.72	---	---	---	---
FIV1	---	000.76	---	---	---	---
FIV3	---	001.25	---	---	---	---
FIV.5/FIVC	---	001.31	---	---	---	---
FIV1/FIVC	---	001.38	---	---	---	---
FIV3/FIVC	---	002.27	---	---	---	---

Figure 5.10 - Results of the FVC Test in Helios Software

5.3 Results of Spirometry Test

FVC Test for Month of February , March , April gave following results.

Table 5.3- Standard Deviation Lung Function Test from Ideal for February, March, April for Non-Asthmatics

	Ideal	Ideal	February	February	March	March	April	April
Sr.No	FVC	FEV1/FVC	FVC	FEV1/FVC	FVC	FEV1/FVC	FVC	FEV1/FVC
1	4.5	84.44	3.97	80.6	4.05	81.56	3.89	81.49
2	4.32	85.88	3.54	82.77	3.22	91.83	3.28	95.73
3	1.9	74.21	1.72	81.98	1.74	83.91	1.73	85.55
4	3.08	78.57	3.16	70.89	3.37	91.69	2.7	84.44
5	2.29	76.86	1.85	95.68	1.78	93.19	1.73	94.22
6	2	71.5	1.35	91.85	1.65	94.87	1.42	92.4
7	2.52	79.76	2.98	84.9	3.02	85.2	2.68	85.8
8	2.56	78.91	2.65	78.87	2.74	77.52	2.71	74.52
9	2.22	83.33	2.02	88.23	2.41	85.48	2.1	92.86
10	3.65	85.48	4.49	73.47	4.41	73.47	4.05	81.73
11	2.65	80.75	2.78	78.06	2.89	80.62	2.82	82.62
12	2.43	77.78	2.47	86.23	2.2	90	2.46	86.99
13	2.8	79.64	2.67	90.56	3.02	91.2	2.94	89.56
14	3.23	77.09	3.83	71.54	3.98	80.25	3.74	81.23
15	2.26	76.55	2.45	71.56	2.59	79.54	2.45	86.12
Mean	2.83	79.38	2.80	81.81	2.87	85.36	2.71	86.35
Std. Deviation from Ideal			0.82759	6.27908	0.8082	6.140006	0.7797	6.068567

Table 5.4 - Standard Deviation Lung Function Test from Ideal for February , March, April for Asthmatics

	Ideal	Ideal	Feb	Feb	March	March	April	April
Sr.No	FVC	FEV1/FVC	FVC	FEV1/FVC	FVC	FEV1/FVC	FVC	FEV1/FVC
1	2.04	75	0.69	34.78	1.1	45.87	0.78	39.88
2	2.94	73.47	2.07	52.17	2.44	61.84	2.14	56.49
3	3.49	82.81	2.01	65.22	2.86	68.47	2.55	66.45
4	3.4	84.12	2.25	69.23	2.56	71.22	2.22	68.59
5	2.59	81.47	2.48	67.22	2.24	64.55	2.35	66.55
6	2.22	78.38	1.89	77.78	1.98	79.25	1.76	71
7	2.78	92.45	2.06	79.15	2.24	75.63	2.14	71.25
8	2	73.5	1.2	51.23	1.4	59.41	1.02	57.77
9	1.99	70.85	1.25	52.5	1.4	59.29	1.27	52.99
10	2.18	77.52	1.44	56.22	1.65	58.62	1.54	58.44
11	3.92	81.38	2.35	58.24	2.6	59.22	2.54	56.33
12	3.93	83.97	3.59	51.62	3.84	54.23	3.65	49.56
13	2.23	75.34	2.27	63.57	2.46	70.08	2.32	65.23
14	2.24	73.32	1.37	51.06	1.61	52.76	1.02	53.33
15	3.53	83.85	2.47	53.85	2.65	55.23	2.17	51.69
Mean	2.77	79.16	1.96	58.99	2.20	62.38	1.96	59.04
Std. Deviation from Ideal			0.80759	13.7022	0.754	11.37197	0.827	12.64831

In this Asthmatics patients category we have following classification of the test subjects

1. 1 patient with severe obstructive disease
2. 9 patients with moderate obstructive disease
3. 5 patients with mild obstructive disease

As According to Patients, Age, Sex, Height, Weight the Ideal Forced Vital Capacity(FVC) and the Ideal FEV1 Ratio Changes. We the investigate the correlation between does the Pollutants PM_{10}, $PM_{2.5}$,Ozone ,NOx affect the Lung Function Test i.e Spirometry Test.

Table 5.5– Inputs for the Correlation test

FVC	Katraj Area Pollution Concentration		
	February	March	April
PM_{10}	132.66	107.32	139.76
$PM_{2.5}$	72.97	68.28	50.49
NOx	16.53	15.2	13.4
Ozone	53.13	51.34	48
Non-Asthmatic FVC	0.807592	0.754163	0.827084
Asthmatic FVC	0.827592	0.80828	0.779759

Table 5.6 – Results of Correlation Test for FVC

	PM_{10}	$PM_{2.5}$	NOx	Ozone
Non-Asthmatic	0.99	0.55	0.34	0.42
Asthmatic	0.41	0.97	0.90	0.89

Asthmatics Exhaling capacity i.e Forced Vital Capacity has a strong positive correlation with the $PM_{2.5}$, NOx , Ozone and a positive correlation with PM_{10} indicating the change in pollutant concentration affects the Lung function capacity.

Table 5.7 – Inputs for the Correlation test

FEV_1/FVC	Katraj Area Pollution Concentration		
	February	March	April
PM_{10}	132.66	107.32	139.76
$PM_{2.5}$	72.97	68.28	50.49
NOx	16.53	15.2	13.4
Ozone	53.13	51.34	48
Non-Asthmatic FEV_1/FVC	13.7022	11.37197	12.64831
Asthmatic FEV_1/FVC	6.279086	6.140006	6.068567

Table 5.8 – Results of Correlation Test for FEV_1/FVC

	PM_{10}	$PM_{2.5}$	NOx	Ozone
Non-Asthmatic	0.77	0.14	0.37	0.29
Asthmatic	0.42	0.97	0.86	0.83

Mean value of the FEV_1/FVC in February is 81.81 for 15 Non-Asthmatics which is lesser than 85.36, 86.35 in March and April indicating more pollution in February similarly for 15 Asthmatics FEV_1/FVC in February is 58.99 which is lesser than 62.38, 59.04. Standard Deviations from the Ideals are taken for FEV_1/FVC 6.28, 6.14, 6.06 for Non-Asthmatics which are lesser in number than 13.70, 11.37, 12.65 for Asthmatic indicating Asthmatics lung functioning. Resultant Correlation Matrix suggests that Asthmatics Exhaling capacity i.e Forced Vital Capacity has a strong positive correlation with the $PM_{2.5}$, NOx, Ozone and a positive correlation with PM_{10} indicating the change in pollutant concentration affects the Lung function capacity. Particulate Matter being the prime Air Pollutant affecting the Asthmatics and Non-Asthmatics at the strongest correlation ratio of 0.99, 0.77 for Asthmatics and 0.90 and 0.97 for Non-Asthmatics indicating their lung function depends on the Atmospheric Air Pollutants. This lowered Air Lung Function affects the Mechanism of Body Immune System , It may Accelerate the growth respiratory related Allergies. It may be the reason to cause Asthma Attacks. The strong correlation of PM_{10}, $PM_{2.5}$, Ozone, NOx with the Lung function Test Parameters.

The Proper understanding of the relation of Air pollution with Human Health requires in-depth knowledge of Pollutant Dynamics and Human Anatomy. We can then specify the Risks, Mechanism and Concentration by which the pollutant affects various systems in the human body. Government of each locality shall carry out this type of study to stress on this effect of Air Pollution on the Human Health .A person with respiratory disease shall take proper care to avoid his exposure to Highly Polluted Air. People with asthma are particularly sensitive to the health risks of outdoor air pollution. Ozone pollution (smog) and particle pollution (soot), the most common air pollutants, are powerful asthma triggers, as are vehicle exhaust, wood smoke and fumes. Because outdoor air quality can be beyond your control, the best defence is knowledge. Knowing the current air quality outside can help you plan your day and make decisions about things like exercise, travel and time spent outside that will best protect your health.The best way to stay informed before you leave your home is by checking the air quality forecast. That forecast uses a color-coded air quality index (AQI) that can help you know how clean or polluted the air will be. People with smartphone can now download the India’s First Air Quality Monitoring app SAFAR from their Smartphone and Check the Air Quality AQI if it is high then the Asthma patients are advised to stay indoors.

Findings from this study are consistent with the substantial international literature relating air pollution to health effects. In addition, an internal coherence of results was observed with pollutants displaying larger effects at the same lag period for different diseases or age groups, or the same pollutant exhibiting similar effects for related health outcomes. Government Hospitals shall undertake operations for the peculiar location shall check the Health status of citizens of that area and produce statistics which make people more informed about the air Pollution. The associations between air pollution and adverse health effects observed in this study do not necessary imply causation. A critical factor in assessing causality in epidemiology is the finding of similar results in multiple studies, in different locations with varying levels of potential confounding factors well designed and conducted research on the health effects of exposure to urban ambient levels of air pollution in developing countries context are needed. Still few such studies have been conducted in these countries. The extent to which factors such as temperature, other meteorological parameters, population susceptibility, etc. are modifying the adverse health effects from exposure to air pollution needs to be more fully understood and quantified.

5.4 Conclusion

Results indicate that a strong correlation between the Pollutants concentration and the Lung Function test Results. The greater amount of pollutants Particulate Matter being the pollutants of the most concern for both Asthmatics and the Non-Asthmatics. Asthmatics are more sensitive to the environmental pollution and the effects on their lung function stats are significant, These Asthmatics that is the reason why have a Higher Risks of Mortality and Morbidity due to Air Pollution. Increased exposure of humans in air pollutants, dietary interventions, rich in plant-derived foods it consists of anti-oxidants which help built-up immunity power in the body, may protect or decrease their effects on different organs. For Prevention of Air Pollution can to take precautionary measure during a high pollution day like staying indoors, avoiding exercise use of equipment's like Air Purifiers, Air Filters and personal protective measures like Respiratory Masks.

CHAPTER 7
URBAN AIR QUALITY MODELLING

Urban air pollution became one of the main factors of degradation of the quality of life in cities. This problem tends to worsen due to the unbalanced development of urban spaces and the significant increase of mobility and road traffic. As a consequence, the total emissions from road traffic have risen significantly, assuming the main responsibility for the disregard of air quality standards [65]. India has experienced a high rate of Urbanisation, higher density of population in cities has more it .The higher population Density with cities like Mumbai having population densities of 20680 person/km^2 has led to crowded space in a urban setting decreased Natural Ventilation of Air Pollutants**.** Using the advanced Computational and Mathematical models pollutant concentrations are estimated. Street canyon models, which might also include simplified photochemistry and particle deposition resuspension algorithms .These models when used in a knowledgeable way they can be very useful in giving insights into the physical and chemical processes that govern the dispersion and transformation of atmospheric pollutants. A study of vehicle exhaust dispersion within different street canyons models in an urban ventilated by cross-wind is conducted at this work to investigate how air pollutant dispersion is affected by wind speed, building height to width ratios, street and building geometries and canyon street number .Air dispersion characteristic modelling in a typical Urban space where there is a restriction of the vehicular pollution emission dispersion. The modelling can be done in different scales from micro-scale (street level) to Meso-scale (whole city) .The nature of our research influences the selection of the size of area which is to be considered. The trend that India's Unplanned development, compact cities, vertical type of growth resulting in decreased air pollutant dispersion. Need of suitable air Dispersion modelling for a particular city as the Geographic, Topographic, and Climatic situation to exactly study. Air Pollution is an escalating problem worldwide fuelled by increasing anthropogenic activities, speedy development, rapid industrialization, transportation, superfluous use of fossil fuel consumption, power needs[66]

7.1 Effects of Compact Urban Cities on Air Pollution Dispersion- Indian Perspective

In Indian cities buildings are getting taller and streets narrower such that majority of citizens will be accommodate but we don’t see the downside of making the city more compact having more skyscraper as the air pollution dispersion will be decreasing. As a result, the air pollution in the urban areas will increase thus reducing the life expectations .Although urban areas comprise a very small fraction of Earth’s land cover [67], over half of global population live in urban agglomerations. India has experienced a high rate of Urbanisation, higher density of population in cities has more it the greater is he concentration on the Urban Air Quality which affects the Health of residents especially in the nearby the streets[68]. Therefore, it is important to monitor, understand, and predict the modifications occurring in local weather and climate due to urbanization, particularly for the perspective of accurate high-resolution weather and air-quality forecasting and climate-sensitive urban design and planning. Cities are characterized by a high fraction of impervious surfaces, which modify both surface energy and water balances, further affecting atmospheric boundary layer (ABL) turbulence and weather processes. Cities are the main “area sources” of air pollutants with detrimental effects on human health and comfort. Cities can generate, modify, and/or amplify many processes behind global changes such as increases in greenhouse gas concentrations, increased water and energy demand, environmental pollution, or change of biodiversity.

7.2 Fundamental of Urban Climate

7.2.1 Concentrations in Urban Street Canyons

The exposure of the population to air pollution in urban areas is made up of three components:

(1) The urban background

(2) The direct impact of road transport emissions on persons within the same street,

(3) The re-circulation of air within a street canyon.

In light winds or when the wind is parallel to the street axis a re-circulating flow will not be set up and the dispersion at the surface may be considered like a box with open lid. The re-circulating and direct components may then be considered equivalent. To describe pollution in street canyons, models of the direct and recirculating components have been proposed. The direct component on the windward side of the street when the street is aligned perpendicular to the wind direction and there is no re-circulation is termed as a street canyon

Figure 7.1 Typical Urban Street Canyon Example

Particulate Matter, Hydrocarbon, Carbon Monoxide ,Nitrogen Oxide Ozone which are most important Traffic-related air pollutants in modern urban agglomerations both in the developed and the developing world. Air quality limit values, whose objective is to protect public health, are frequently exceeded, particularly in busy streets and urban areas. Evidence is constantly emerging related to the human exposure to increased pollutant concentrations in densely populated urban areas in contrast with the proven adverse effects on human health. It is imperative to fully understand the pollutants behaviour within confined urban canopy areas. The dilution and removal of vehicular traffic exhausts in urban street canyons is of great importance for the public health and quality of life of people living or working in city centers.

7.2.2 Urban Boundary Layer(UBL)

Urban Boundary Layer (UBL) creates a dome of rising warm air and low pressure. As ground surfaces are heated rapid evapotranspiration takes place**.** The buildings modify the flow field, influencing air exchanges and the dispersion of pollutants. In urban areas where population and traffic density are relatively high, human exposure to hazardous substances is significant. Due to this concern, the street canyons are considered as hot spots for air pollution problems. Irregular shape buildings enhances turbulence and vertical mixing in the atmosphere, while W/H ratios of urban canyons affect street air dispersion.

7.2.3 Atmospheric Boundary layer (ABL)

Atmospheric boundary layer (ABL), part of the troposphere, is directly influenced by the land surface processes. The transfer of energy between the surface and the air is partly accomplished by the turbulent eddies. Atmospheric turbulence in the ABL is produced primarily by wind shear and buoyancy. Diurnal variations in wind speed, static instability, turbulent exchange and convective activity in the ABL are significant over tropics2-3.

Generally, all kinds of energy exchange with surface atmospheric boundary layer plays important role in transporting heat, momentum, moisture besides pollutants such as friction, sensible and latent heat flux occurs in ABL 4-5 . In general, ABL height varies both in time and space, from hundreds of meters to a few kilometres. The ABL height (h) is a crucial parameter in weather and climate models[73]. This height controls the vertical extent, concentration and transformation of atmospheric pollution and has influence on the concentration of trace gases and ozone in the lower troposphere.

The vertical mixing of atmospheric pollutants are strongly influenced by the height of the ABL, which acts as an interface between the more polluted regions near the earth's surface and the relatively cleaner free atmosphere above. Thus, air quality measurements are directly related to the ABL parameters.

7.2.4 Urban Heat Island (UHI)

Atmospheric temperature rise experienced due to heat island phenomenon has been commonly associated to cities, These type of surfaces are dark, dry which are characterized by low albedos, high impermeability and favourable thermal properties which are capable of heat energy storage and subsequent heat release . The lesser is the sky view factor the greater is the absorbance and the re-emittance from their surface in the urban canyon. Due to this factors urban areas increasing their temperatures in relation to their rural counterparts which have more vegetation, and thus their temperatures are maintained through the evapotranspiration progression , shades of trees and interception of sun's radiation. Higher daytime and night time temperatures affect human health, including general discomfort, respiratory difficulties, heat cramps, heat strokes, and heat related mortality. Urban heat islands make extended heat waves more damaging, particularly to sensitive populations such as children and older adults. The remotely sensed urban heat island. It is observed by using thermal infrared data that allow to retrieve land surface temperatures. Usually, close relationships between the near surface air temperatures and land surface temperatures have been found. Therefore, the surface urban heat island is a reliable indicator of the atmospheric urban heat island

7.3 Factors Influencing Urban Air Quality

Megacities are extreme examples of the continuously growing urbanization of the human population that pose (new) challenges to the environment and human health at a local scale.

where Q is the emission strength per unit length of street, W is width of street, σ_w is the vertical turbulent velocity fluctuation including traffic generated turbulence near the ground in the street, h_o is the initial dispersion in the wake of vehicles typically 2m, and u_b is the wind speed at the street level. The magnitude of the re-circulating component of the concentration on the windward side of the street when the vortex extends through the whole street canyon is of order [68,69].

$$C_{dir} = \sqrt{\frac{Q}{W\sigma_w} \ln \frac{ho + (\sigma w/_{u_b})(W)}{h_o}}$$

where Q is the emission strength per unit length of street, W is width of street, □w is the vertical turbulent velocity fluctuation including traffic generated turbulence near the ground in the street, h_0 is the initial dispersion in the wake of vehicles typically 2m, and u_b is the wind speed at the street level.

The magnitude of the re-circulating component of the concentration on the windward side of the street when the vortex extends through the whole street canyon is of order [68,69].

$$C = \frac{Q}{W\sigma_{wt}}$$

where σwt is the rms vertical turbulent velocity fluctuation at roof level.

Despite the fact that policies regarding on the sustainable development are present, but to manage spaces with rapid development, active industrialization and high traffic volumes form a different scenario for the administration. Monitoring air quality in urban areas requires more monitoring stations to be positioned near to cities whereby it is unmanageable and not practical. Due to that limitation, monitoring stations are planned for large scale air quality model [70]. Heavy traffic and slow vehicle movements seem will trap the pollutant emission inside of the urban geometry. The circulation of pollutant between buildings will worsen if there is no natural ventilation or slow background wind speed. However it is crucial to monitor air pollution in urban cities in order to have a better and healthy living standard. But to deploy monitoring stations at street level will affect the cost. This is one of the reasons why it is difficult to have a Micro scale model for air pollution monitoring in urban area . Another alternative is to perform air quality modelling in the urban area [71,72]. Since the agent (pollutants) is a moving object, appropriate modelling approach in a rapid development place need to be deliberate comprehensively.

In a practical approach, the urban air quality model requires several data input [66]. The geometry of an area model is important in order to produce a more accurate result. To date, there are complications in data acquisition for rapid development places. New data input like building geometries (e.g. Building's height, width and gaps) need to be collected from ground measurements and re-calculated with other inputs (e.g. street geometries). This data is important in air quality modeling (dispersion model) to produce an accurate output. In air dispersion models, it consists of two major groups of data: meteorological and physical data. Meteorological department monitors information regarding to meteorological circumstances.

7.4 Factors on which Air Dispersion Model depends

7.4.1 Geographical Setting

Each settlement has its unique geographical location. They can be located in mountainous areas, in flat plains, along rivers, in deserts, or at the coast. For example, settlements which are surrounded by mountains or hills show different air qualities than settlements at the coast. Hills deflect the flow of contaminated air, either vertically or horizontally. The extent of this deflection depends on vertical atmospheric stability. Wind carrying pollutants may flow up and down the valley. Air movement may be affected by the depths of valleys. On the other hand, coastal areas have less or even no geographical barriers limiting the dispersion of pollutants. The air is often cleaner compared to settlements inland. Mexico City is a good example of geographical barriers to air pollution dispersion, whereas Los Angeles experiences climatological barriers. London and Chicago are examples of relatively good ventilation.

7.4.2 Climatological and Meteorological Factors

Settlements are located in different climatic zones. Air pollutants behave differently in tropical climate than in dry or cool climates. The dispersion of air pollutants is influenced by the micro-climate and meteorological factors such as wind speed, wind direction and turbulence, as well as temperature, precipitation and humidity. Higher wind speed near air pollutant discharge points leads to rapid discharge and dilution of these pollutants. Low wind speeds cause higher concentrations of pollutants. Air pollution problems may reach alarming levels when climatic conditions prevent the effective dispersion of pollutants. This refers to places where the temperature increases with height (negative lapse rate or temperature inversion). Such a situation inhibits turbulence and allows less mixing since air near the ground is denser than that above ground. Hence, vertical dispersion is inhibited. This usually occurs in countries with a cold, temperate climate.

In conditions where temperature decreases with height, the atmosphere is unstable. Due to the vertical mixing of the air, pollutants are rapidly dispersed.

7.4.3 City Planning and Design

The structure of a settlement and its physical development greatly influences the quality of the air. The following list names some factors which have an impact on the transport and dispersion of pollutants: · urban sprawl - increases demand for commuting and generation of traffic;dense central business districts - high rise buildings cause ‘street canyon’ effects; Urban Air Quality Management Toolbook - Toolkit 4 congested low income settlements - mixed uses and activities; · industrial areas - pollution emitting factories; · inner city highways and other transport infrastructure - with individual cars and freight transport; · inner city forests, green areas and urban agriculture - absorbing the greenhouse gas CO_2 (and, in turn, releasing oxygen) and ‘filtering’ particles and dust.

7.4.4 Human Activities in Urban Areas

Most air pollution within urban settlements is caused by human activities. This includes mobility behaviour, industrial development, production and use of energy (for processing, heating and cooking), waste management and activities which produce dust. Depending on the wealth of a society, their life style, and/or their environmental awareness the intensity of air polluting activities differ. For example, poor settlements are often confronted with indoor air pollution due to inappropriate cooking and or heating devices. Also the inappropriate disposal and burning of waste contributes to bad air. Cities in emerging economies usually struggle with pollution from heavy industries. In developed economies, traffic is the major contributor to air pollution.

GIS is all about spatial data and the tools for managing, compiling, and analysing that data. ArcGIS Spatial Analyst extension provides a toolset for analysing and modelling spatial data. A set of sample points representing changes in landscape, population, or environment can be used to visualize the continuity and variability of observed data across a surface through the use of interpolation tools. These changes can be extrapolated across geographic space. The morphology and characteristics of these changes can be described. The ability to create surfaces from sample data makes interpolation both powerful and useful.

Once the air situation in the city is well understood, from both the technical and social points of view, planning and management towards solutions can begin. When using the Environmental Planning and Management (EPM) approach, stakeholders in the city are to be actively involved in the entire process – from problem identification to finding strategies and implementing solutions. The city plays a coordinating and facilitating role in this process.

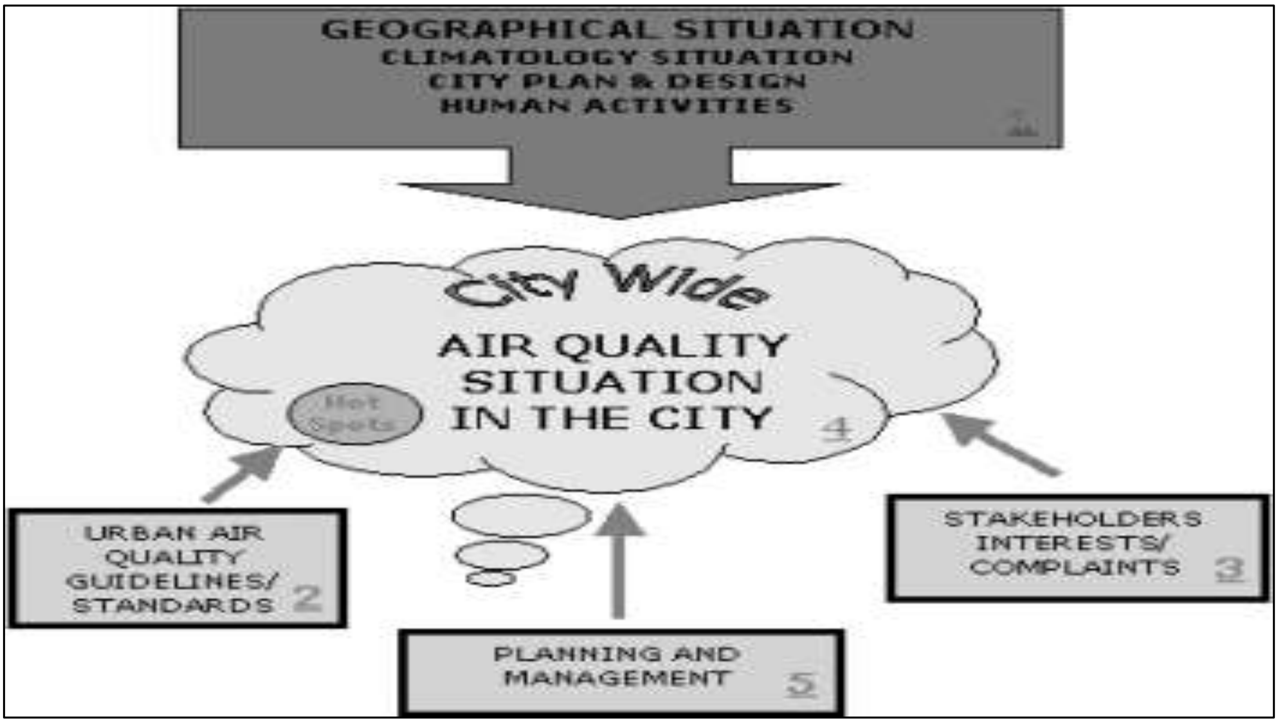


Figure 7.2 - Coordinating and Facilitating role of City in Air Quality

Nowadays the term "air pollution model" usually refers to a computer program, but in the past it has also included hand calculations or use of charts and tables from simple handbooks. A dispersion model is essentially a computational procedure for predicting concentrations downwind of a pollutant source, based on knowledge of the emissions characteristics (stack exit velocity, plume temperature, stack diameter, etc), terrain (surface roughness, local topography, nearby buildings) and state of the atmosphere (wind speed, stability, mixing height, etc)

These emissions are subject to dispersion and chemical interactions which generate pollutant concentrations in the atmosphere. It is also useful to distinguish between:

•Primary pollutants that are generated at source and then dispersed, for example direct emissions in the form of particulate matter (PM) and nitrogen oxide emissions (NO_x , a combination of NO (nitrogen monoxide) and NO_2);

•Secondary pollutants that are formed by chemical interaction, for example the oxidation of NO into NO_2 and ozone formation;

•Transboundary pollutants, which are not generated locally but are blown in from other areas or countries.

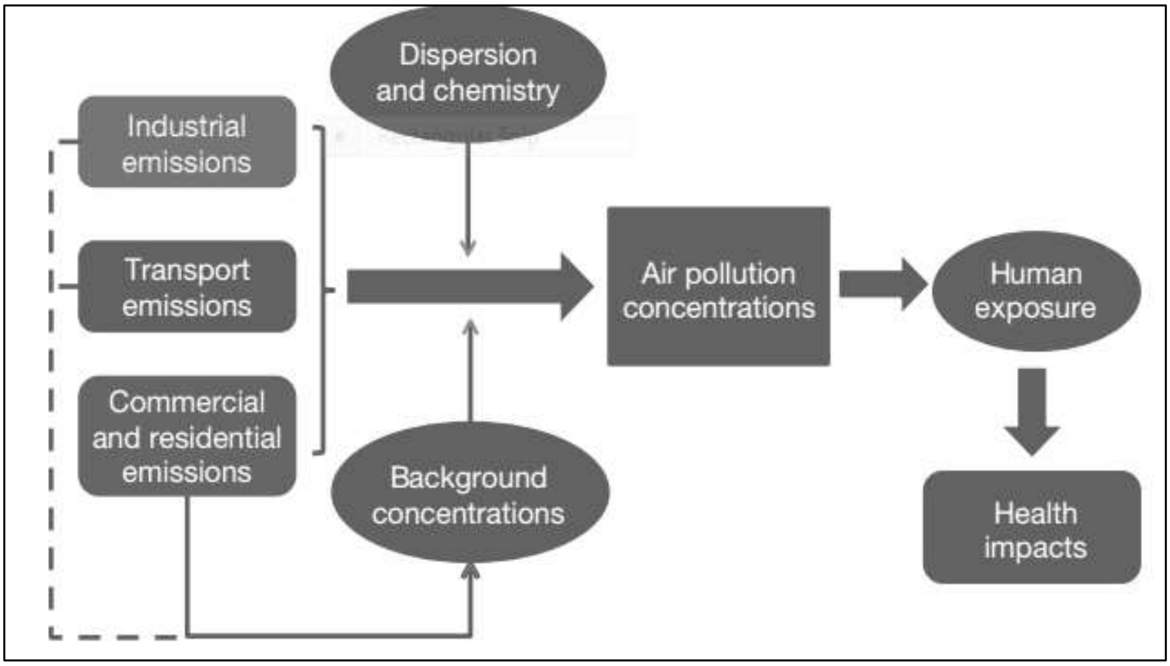


Figure 7.3- The relationship between emissions, concentrations and health impacts

7.5 Effect of Buildings and Building Wakes on Plume Dispersion

Many industrial stacks are located on top of buildings or in plant sites where there are large buildings nearby. One of the major challenges in regulatory dispersion modeling is to account for the effects of buildings on the near-field dispersion of a plume. There is often a single, large structure that dominates the scene, such as a nuclear reactor building. Most research on this problem had been done for releases on or nearby individual buildings.

Municipal administrations are challenged to respond to these 'subjective' perceptions. Both the technical assessment and the analysis of the subjective perceptions are important in identifying areas that require improved management. [74] It is important to distinguish between city-wide air quality problems (like temperature inversion which worsens 'smog' in the city) from the so-called hot spots that are area specific problems (like a factory causing health problems within the immediate neighbourhood). [75] Once the air situation in the city is well understood, from both the technical and social points of view, planning and management towards solutions can begin. When using the Environmental Planning and Management (EPM) approach, stakeholders in the city are to be actively involved in the entire process – from problem identification to finding strategies and implementing solutions. The city plays a coordinating and facilitating role in this process.

7.6 Urban Scenario in India

Urban population in India according to 1901 census, was 11.4%. This count increased to 28.53% according to 2001 census, and crossing 30% as per 2011 census, standing at 31.16%. According to a survey by UN State of the World Population report in 2007, by 2030, 40.76% of country's population is expected to reside in urban areas.

The Future planned Indian Cities of Durgapur, West Bengal, Greater Noida, Uttar Pradesh, Lavasa , Maharashtra, Mohali, Punjab ,GIFT, Gujarat, New Town, Kolkata, Sri Ganganagar, Rajasthan, Sricity, Andhra Pradesh and so forth are spreading at a fast pace in its width there are to take into consideration the effect of the congregation of the air pollutants due to peculiar geometry of the design of the buildings urban canopy. The World bank has given status of Indian Urban Area as it is going to be 50% by 2050 from 2013. So we need to built this future areas in such a way that it mitigates the effect of Urban Heat Island and have a natural ventilation in the cities.The Cities have experienced Rapid Urbanisation which has bought more clusters of tall buildings , compact urban space and the smaller street geometry in the metro cities it influences in quite large manner the urban climate [76,77].

Its very necessary to study the urban canyon at a micro-scale and how it does affect the overall climatic condition on a urban scale also the concept associated with it urban canopy, urban heat island Roughness subsurface and boundary layers. City pollution is soaring in summer because vast swathes of paving and brick retain too much heat at night, and tall buildings block the cooling winds that should clear airborne pollutants. Urban pollutant concentrations can be 10 times higher than those of the ‘clean’ atmosphere and air temperatures can be on the average 2°C higher. The fluxes of heat, moisture, and momentum are significantly altered by the urban landscape and the contrast between the urban and ‘undisturbed’ climates is further enhanced by the input of anthropogenic heat, moisture, and pollutants into the atmosphere.

7.7 Differences between Urban and Rural Air Dispersion Climatology

The urban situation presents special problems to the air pollution modeller. In many situations the starting point for urban dispersion is a simple dispersion scheme applicable to rural areas suitably modified. The presence of the urban area introduces two complicating features to the rural boundary layer built up in the approach flow to the urban area, illustrated in Figure 6.4. The roughness elements of the urban area are typically much larger than the rural roughness elements and the urban area is associated with surface heating.

These effects introduce a developing boundary layer over the urban area, which modifies the incident profile. In addition one can visualise a modified surface layer above the roughness elements. In ideal convective and stable atmospheric boundary layers the wind profile near the surface should follow a logarithmic profile characteristic of neutral conditions.

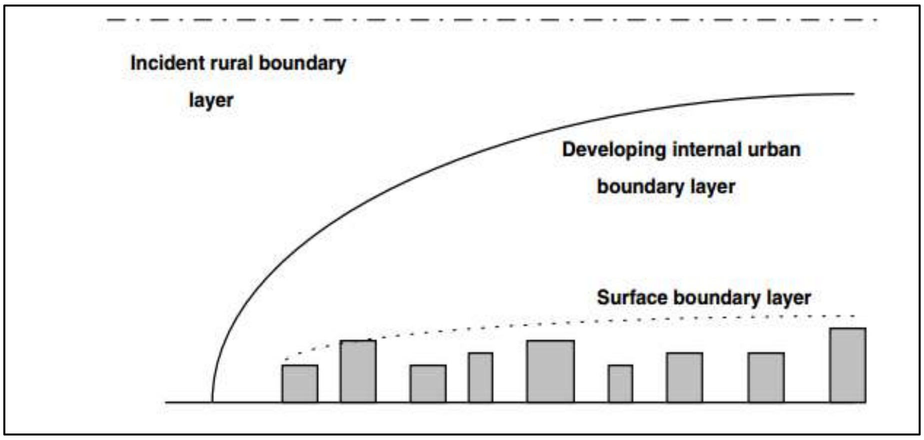


Figure 6.4 – Development of internal urban boundary layer

A great number of factors can influence the air quality of your urban settlement. This tool depicts the most relevant factors: a. geographical setting; b.climatological and meteorological factors; c. city planning and design; and d. human activities in urban areas

7.8 Development of Urban Heat Island(UHI)

A heat island can occur at a range of scales; it can manifest itself around a single building ,a small vegetative canopy or a large portion of a city. Depending on geographic location and prevailing weather conditions, heat islands may be beneficial or detrimental to the urban dweller and energy user. Generally speaking, low and mid-latitude heat islands are unwanted because they contribute to cooling loads, thermal discomfort, and air pollution whereas high latitude heat islands are less of a problem because they can reduce heating energy requirements. The principal reason for the night-time warming is that the short-wave radiation is still within the concrete, asphalt, and buildings that was absorbed during the day, unlike suburban and rural areas. This energy is then slowly released during the night as long-wave radiation, making cooling a slow process. Two other reasons are changes in the thermal properties of surface materials and lack of evapotranspiration (for example through lack of vegetation) in urban areas. With a decreased amount of vegetation, cities also lose the shade and cooling effect of trees, the low albedo of their leaves, and the removal of carbon dioxide

Materials commonly used in urban areas for pavement and roofs, such as concrete and asphalt, have significantly different thermal bulk properties (including heat capacity and thermal conductivity) and surface radiative properties (albedo and emissivity) than the surrounding rural areas. This causes a change in the energy balance of the urban area, often leading to higher temperatures than surrounding rural areas Other causes of a UHI are due to geometric effects. The tall buildings within many urban areas provide multiple surfaces for the reflection and absorption of sunlight, increasing the efficiency with which urban areas are heated. This is called the "urban canyon effect". Another effect of buildings is the blocking of wind, which also inhibits cooling by convection and pollution from dissipating. The "Street Canyon Effect "The modification of the characteristics of the atmospheric boundary layer by the presence of a street canyon is called the street canyon effect .Street canyons affect temperature, wind and wind direction and consequently the air quality with in the canyon.

7.9 Effect on temperature due to Urban Heat Island

Urban canyons contribute to the urban heat island effect. The temperature inside the canyon can be elevated 2-4 degrees C. Studies of temperature phenomena consider irradiance, angle of incidence, surface albedo, emissivity, temperature and SVF. For high SVF, the urban canyons cool quickly, because more sky is available to absorb the heat retained by the buildings. With a low SVF, the canyon can retain more heat during the day, creating a higher heat release at night. A study done by [79,80] investigated the energy exchanges in an urban canyon in mid-latitudes in fine summer weather. The study showed that the amount of surface energy at various times within the canyon depends on canyon geometry and orientation. Canyons with north-south orientation were found to have the floor being the most active energy site. In such a canyon, 30% of midday radiant surplus is stored in the canyon materials (the buildings)..

7.10 Effect on wind due to Urban Heat Island

Street canyons can modify both the speed and the direction of winds. The vertical wind velocity approaches zero at the roof level of the canyon. Shear production and dissipation are high at the roof level and a strong thin shear layer is created at the building height[90] Turbulence kinetic energy is higher near the downwind building than near the upwind building because of stronger wind shears. The resulting flow patterns inside the canyon depend on the wind direction with respect to the street orientation direction.

7.10.1 Effect of Wind parallel on Urban canyon

When the roof level/background wind direction is parallel to the street, a channelization effect is seen where winds tend to be channeled and accelerated through the canyon. In situations where the street width is non-uniform, a Venturi effect is seen when winds funnels through small openings, further enhancing the acceleration of winds .Both these effects are explained by the Bernoulli's principle. The along street wind and transport can be significantly different for short and long canyons as the corner vortices has a stronger influence in short canyons. [91]

7.10.2 Wind perpendicular to Canyon

When the roof level/background wind direction is perpendicular to the street, a vertically rotating wind flow is created with a centered primary vortex inside street canyons. Based on the aspect ratio, different flow regimes are defined in street canyons. In the increasing order of aspect ratio these flow regimes are: isolated roughness flow, wake interference flow and skimming flow. The total number of vortices made and their intensities depends on many factors. Numerical model studies done for isolated street canyons have shown that the number of vortexes made increases with increasing aspect ratio of the canyon. But there is a critical value of the ambient wind speed, above which the number and pattern of vortexes become independent of the aspect ratio.

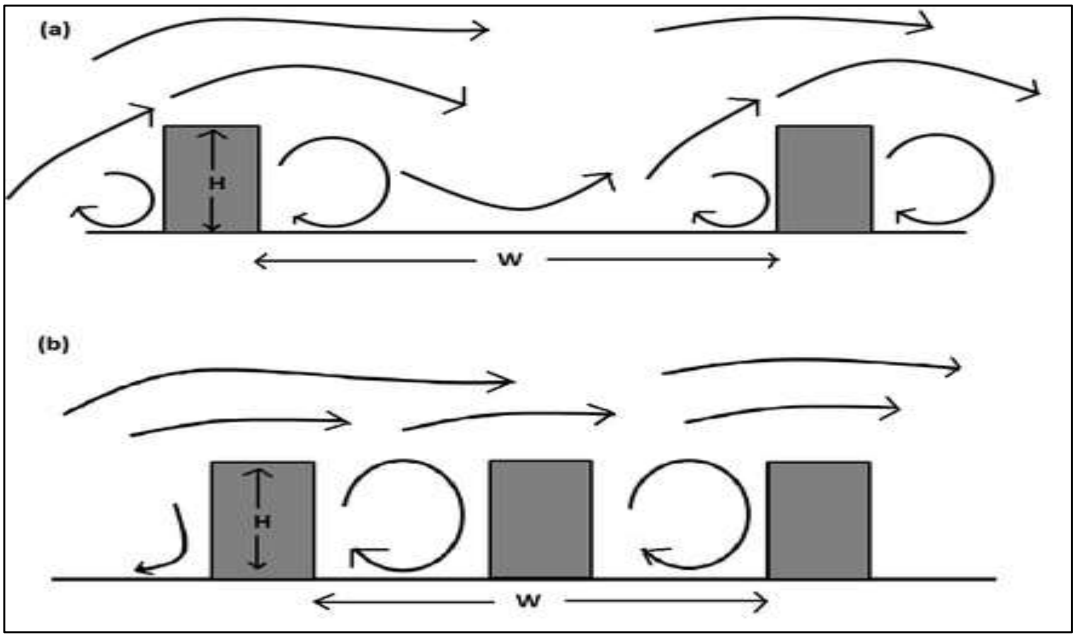


Figure 7.5 The comparison of (a) isolated roughness flow and (b) skimming flow regimes in a street canyon 78

7.11 Components of Urban Canyon Modelling

7.11.1 Emissivity of the material

The emissivity of a material is the relative ability of its surface to emit energy by radiation, it is also important related to the UHI phenomenon or characterization of urban areas. As the Urban Agglomerate is built up usually by Bricks, Concrete and Asphalt there is enormous amount of heat emitted which are 0.93,0.88,0.93.High Emissive Materials emits radiation at night making the temperature of the Surface Urban Heat Island is comparatively higher even in Nights than the rural counterparts.

7.11.2 Albedos of the Material

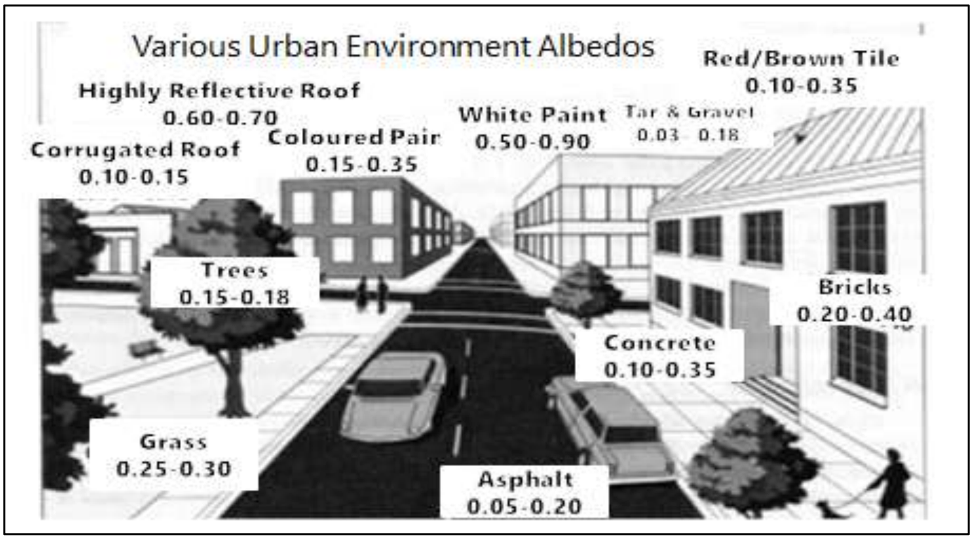


Figure 7.6 Albedos of different material in Urban City

Commonly used materials like concrete, brickwork and bitumen warm up rapidly in the day time in contrast to waterways and parks. Due to the nature of the surface its albedo is lower. Much more heat is absorbed and conducted through the material. This heat is then slowly released during the night, adding warmth to the urban atmosphere. This keeps urban climates relatively high and the contrast between the urban environment and the rural fringe is greatest at night.

7.11.3 Sky View Factor(SVF)

It is one of the Most Important factor in Urban Heat Island required as a parameter on its modelling. Using ArcView GIS and the possibilities of the 3DSkyView Tool .SVF is the ratio of the radiation received (or emitted) by a planar surface to the radiation emitted (or received) by the entire hemispheric environment [80].

Visible Sky Area divided Total Sky Area allots the SVF. SVF is a dimensionless value that ranges from 0 to 1. A SVF of 1 denotes that the sky is completely visible; for example, in a flat terrain. When a locations has buildings and trees, it will cause the SVF to decrease proportionally. The intensity of the maximum night time urban heat island presents a linear relationship with the Sky View Factor.

7.11.4 Net Radiation Flux

Net Radiative Flux of the underlying surface is difference between the absorbed radiant energy and that emitted by the underlying surface, the atmosphere or by the earth-atmosphere system. Greatest variation of meteorological parameters in urban areas are caused due to short wavelengths [92]. long-wave (i.e., infrared) radiation are as a result re-emitting from the urban surface downward to where it is retained by the ground.

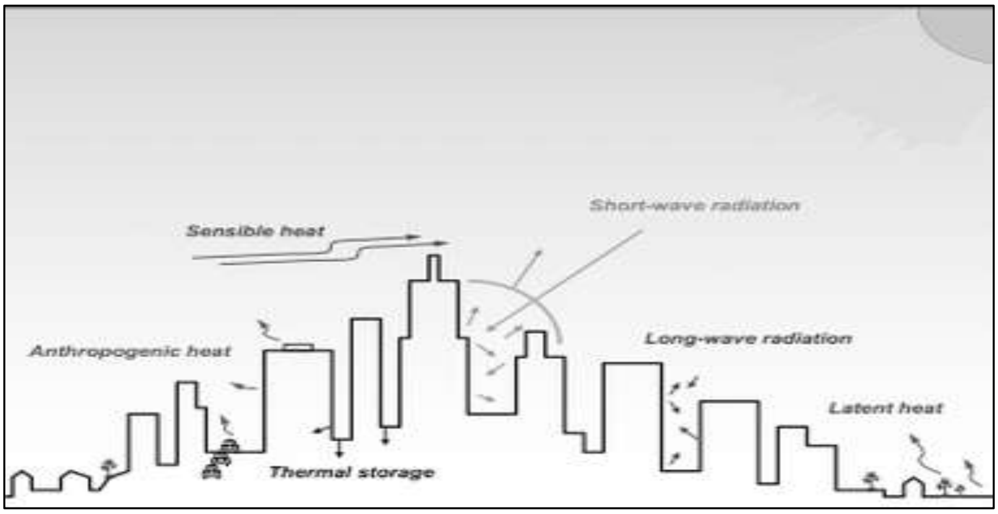


Figure 7.7 Typical Radiation Energy flow in a Urban Settings

Anthropogenic heat, low wind speeds, and air pollution in urban areas can contribute to UHI formation, there are two main reasons for formation of UHI

1.Due to impermeable and watertight material used in the new-age construction the moisture is been trapped this does not allow heat to dissipate in the atmosphere;

2.In a canyon set-up dry, dark surfaces can reach upto 88°C and the vegetated surface with moist soil can reach only upto 18°C building and pavements trap more heat of the sun's energy

7.11.5 Windward and Leeward face of the building on Urban Canyon

In the transverse vertical plane at mid-canyon show that the pollutant concentrations has higher concentrations at the leeward face than that at the windward faces, and has higher concentrations above downwind buildings than that above upwind buildings, Longitudinal distributions of pollutant concentrations at leeward and windward faces show decreasing of the concentration with increasing building height. While calculating the impacts of the pollutant it is important to specify which direction of walls and if these are unequal in dimension that the whole models changes as the dispersion characteristics will change.

7.12 Distinction between Urban and Rural Energy Surface Balance

(a)Sensible heat flux is greater due to the man-made materials like more use bricks, cements, paving and intensification of surface area,

(b)Latent heat flux is lower due to a lower fraction of vegetative land-use cover,

(c)Urban surfaces have higher thermal inertia due to high heat capacity of the man-made surfaces, leading to a non-negligible storage flux,

(d)Complex processes of shadowing and multiple reflections affect short-wave radiation fluxes, and the wide range of materials affect the emissivity and thus long-wave fluxes, resulting (surprisingly) in little difference in net radiation flux, and

(e)Anthropogenic heat sources act in addition to the solar-driven energy balance, effectively increasing the sensible heat flux. The urban surface energy balance drives not only the temporal evolution of the urban heat island (UHI), but also the evolution and vertical structure of the UBL.

Roughness elements are large, and exert significant drag on the flow. An urban roughness sublayer (RSL) can be defined of depth between 2–5H, where H is the mean building height. Within this layer, flow is highly spatially dependent Figure 6.8; turbulence can dominate the mean flow; and turbulence has different characteristics from the flow in the inertial sub-layer (ISL) above, where the turbulence is homogeneous and fluxes vary little with height. The urban canopy layer is defined as the layer up to mean roof height.

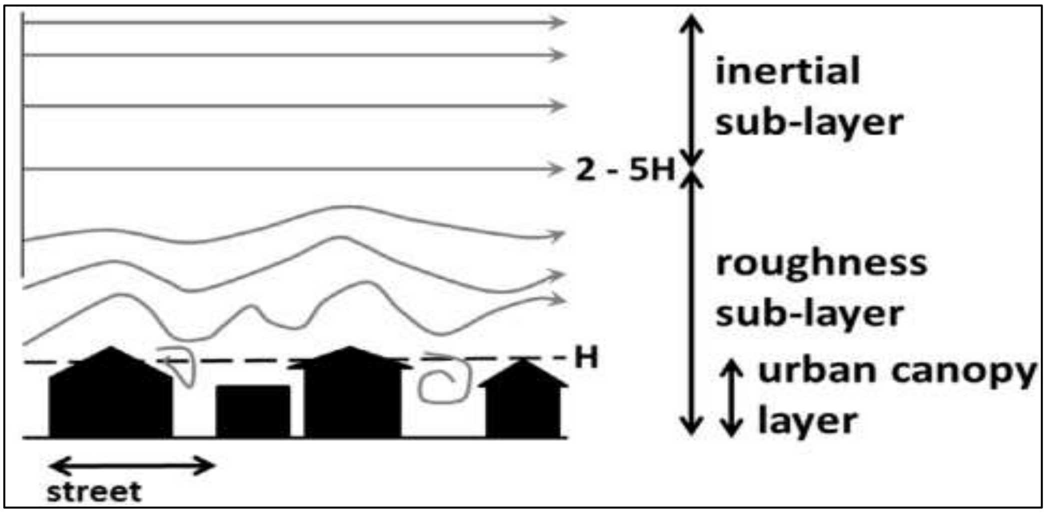


Figure 7.8 Schematic diagram of roughness and inertial sub-layers. Grey arrows indicate streamlines. Dashed line indicates mean building height H.

The urban areas offer an obstruction which leads to upward movement of winds contribute to increased rainfall patterns over the city that are most pronounced to the leeward side of the city. When air passes over the UBL it begins to sink leading to lesser precipitation at the leeward rural area so the design of the Compact Urban cities to such an extent that it creates such indifference of the orographic monsoon.

Trees and vegetation provide shade which helps lower surface temperatures. They also release water to the air (evapotranspiration), which helps cool the area. Urban areas have more dry, unshaded surfaces (paving and rooftops), which evaporate less water.

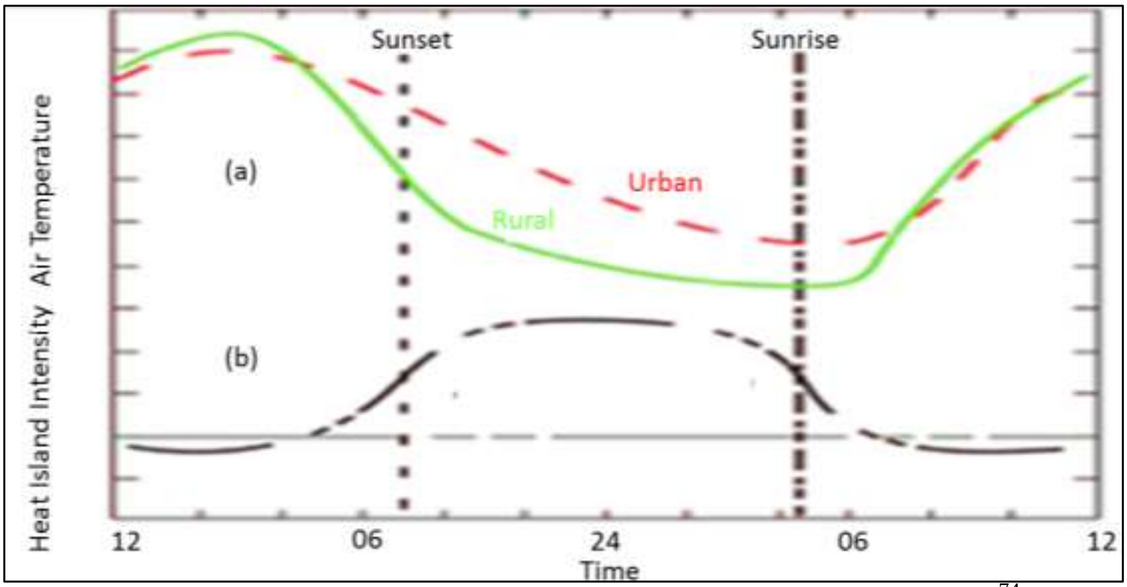


Figure 7.9 Diurnal Heat Change With Calm Atmospheric Conditions [74]

As shown in Figure 7.9 Section A During the day the heat is absorbed by the building surface material and during nights it reemits that is why the cooling is far lesser in urban area in the Time 18:30 to 5:30. So in nights temperature is higher in the urban areas as compared to the rural areas. Urban areas are characterised by 75-100 percent impermeable material and experience have less evapotranspiration than rural areas, which may have only 10% impermeable material. This difference contributes to higher surface area temperatures.

The Pollutants when in atmosphere are either of these fates in their lifespan which are Advection Moving along with air in the atmosphere which is given by expression J=C*U

Where J=Advection, C=concentration, U=Velocity of the flow ,Diffusion process through which pollutant molecules move through air which is given by $Jd=-D\ \partial C/\partial x$ or Dispersion When a pollutant moves dissolved in volatilized in air.

$$\text{Change in pollutants concentration} = \text{Ma} - \text{Sd}$$

Where M_a = Movement due to advection S_d = Spreading due to Diffusion/dispersion

7.13 Method for Street Canyon Modelling

The issue of dispersion of the atmospheric air pollutants is completely different in case of street. The results of this air quality models can be used for air quality management and traffic control, urban design planning, interpretation of monitoring data, time scale pollution forecasting, etc. Although there are no clear-cut distinctions between different categories, models might be classified into groups according to their physical (e.g. reduced-scale) or mathematical principles (e.g. box, Gaussian, CFD) and their level of sophistication (e.g. screening, semi-empirical, numerical). Some of these (often overlapping) categories and corresponding models [94]. Dispersion models gives present and future air pollution levels roadside air quality by providing predictions with time-based and three-dimensional variations.

7.14 Effect of Street Geometry on Street Canyon

The term street canyon ideally narrow street with taller buildings lined up continuously on both the sides that is (H/L). A canyon termed as regular, if it has an aspect ratio about equal to 1 and no major openings on the walls. Finally, the length (L) of the canyon usually expresses the road distance between two major intersections, subdividing street canyons into short ($L/H\approx3$), medium ($L/H\approx5$), and long canyons ($L/H< 7$). Urban streets might be also classified in symmetric (or even) canyons, if the buildings flanking the street have approximately the same height, or asymmetric, if there are momentous differences in building height in opposite direction to each other. This canyon geometry play an important role in the fate of atmospheric pollutant.

7.15 Effect of Street Geometry Wind flow

In the street canyon we take into consideration the microclimate and the urban geometry rather than the mesoscale forces regulatory the climate of the boundary layer . A clear distinction should be made between the synoptic above roof-top wind conditions and the local wind flow within the cavity of the canyon (Figure 7.10).

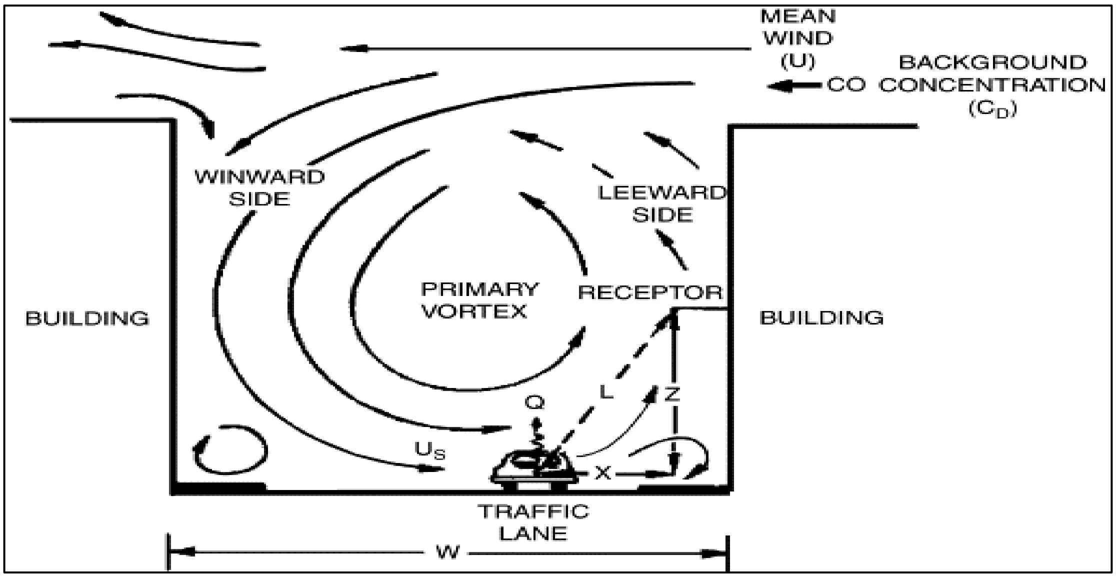


Figure 7.10 The Flow of the wind in Urban Agglomerate

Depending on the free stream winds having velocity can be having 3 main dispersion conditions can be identified: (i) condensed winds lower than 1.5m/s,

(ii) Upright flow for synoptic winds over 1.5 m/s blowing at an angle which is more than 30° to the canyon area, and

(iii) Lateral or just lateral flow for winds over 1.5 m/s. In the case of Upright flow, the upwind side of the canyon is usually called leeward.

3 typical regimes of winds might be observed in the case of study of cross section in the mid-canyon region with speed of the winds greater than 2 m/s [95] (Figure 7.11)

(a) isolated roughness flow, (b) wake interference flow, and (c) skimming flow.

For wide canyons (H/W<3), the buildings are well spaced and act essentially as isolated roughness elements, since the air travels a sufficient distance downwind of the first building before encountering the next obstacle.

Figure 7.11 - Airflow around different structures such as tall and short buildings, streets

The Flow of Air in an Urban Area can be primarily categorised into-

(A) Strong Flow deflected down the building

(B) Calm zone develops between buildings

(C) Combination of large building with streets form canyon accelerated airflow.

As buildings become more closely spaced {H/W≈0.5), the disturbed air flow has insufficient distance to travel just before encountering the downwind building, resulting in wake interference flow. In the case of regular canyons (H/W≈ 1), the bulk of the synoptic flow skims over the canyon producing the skimming flow, which is characterised by the formation of a single vortex within the canyon.

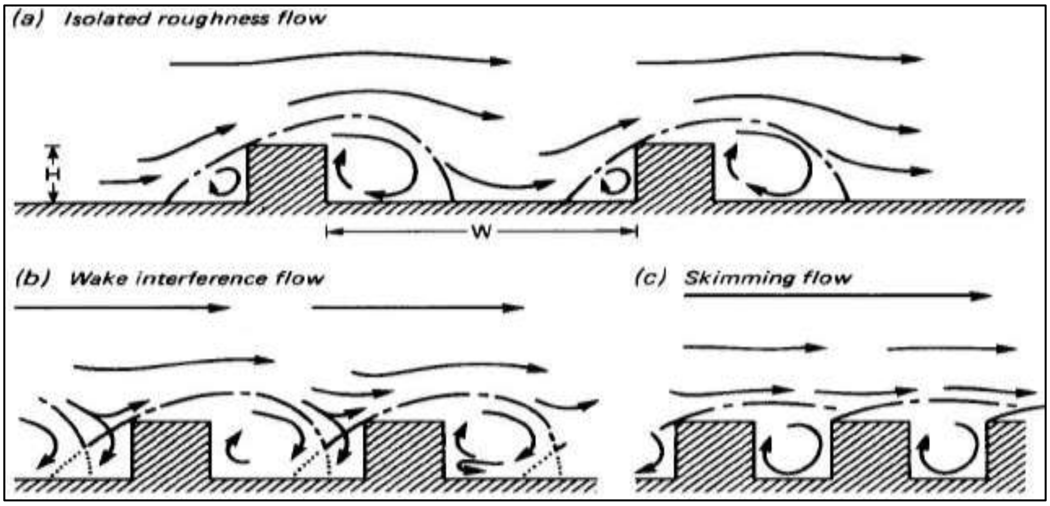


Figure 7.12 The flow regimes associated with air flow over building arrays of H/W

The stability of the atmosphere and also it has its shape and also heating of walls strength and shape of the wind vortices are affected.

7.16 Pollutant dispersion in Microscale level

Dispersion of gaseous pollutants in the vertical direction of the atmosphere and in the lateral direction with the associative streets [95]. With greater L/H the maximum street-level concentration occurs when synoptic winds are parallel to the axis of the street. The accumulation of emissions along the line source outweighs the ventilation induced by the parallel winds .Due to Low synoptic favours air pollution augmentation in urban areas [76]. When the synoptic wind speed is below 1.5 m/s, the wind vortex within the canyon disappears and the air stagnates in the street). [96]declared coarse particles are to be monitored in the street canyon as compared to the finer particles as the later disperses very quickly just like gases into the atmosphere. Models are to be designed as according taking into consideration cities urban heat flux, geometry, Atmospheric Stability for that particular geographical location of the city. Urban Canopy Models have three components namely roads, roofs and walls characterized by the size of the street canyon and the building and is thus able to take into account the sink of momentum over the complete structure of the building, along with shadowing and the radiation trapping effects. The Urban canyon Modelling is essential for the setup of the new industry in Urban so its influence is essential to ensure that the location has its pollutants levels in limits.

7.17 Air Quality Model Requirements

The model has to be able to predict rates of diffusion based on measurable meteorological variables such as wind speed, atmospheric turbulence, and thermodynamic effects. The algorithms at the core of air pollution models are based upon mathematical equations describing these various phenomena which, when combined with empirical (field) data, can be used to predict concentration distributions downwind of a source. Streets as considerable parts of urban open spaces have a significant role in creating the urban microclimates. As street geometry and orientation influence the amount of solar radiation received by street surfaces and also airflow in urban canyons. This paper discusses the current literature and evidence for the effects of street design on the urban microclimate with highlighting the impacts of streets geometry (H/W ratio) and orientation on airflow and solar access in an urban canyon. Researchers conducted on this term have proved that street's geometry and orientation are key factors in providing a pleasant microclimate at pedestrian level in an urban canyon.

7.18 Methodology of Applying Model

The most suitable of Air Quality Model is used STREET BOX Model developed the simple mathematical model STREET BOX, which assumes a uniform concentration distribution within a street canyon and is based on the concept of a turbulent intermittent shear flow shed from the roof of the upwind building.

The street canyon module based on STREET-BOX gave predictions comparable to the measured values at both the sites, despite the significant differences in street geometry.

1) it touches all people in their homes, shops, streets and so on;
2) it cannot be avoided like the industrial emissions which can be translated out of the city.
3) Imposing strong restrictions by local governments and international organizations is needed
4) Plantation of trees on the sides of the canyon , on highways

A small region of positive stress just above the upstream obstacle is seen for all canyon openings. [98] study the Influence of trees on the dispersion of pollutants in an urban street canyon they modeled the trees with spherical crowns and positioned inside the street canyon, varying crown diameter, crown permeability, trunk height and tree spacing

In this study, vehicular emissions were calculated using the hourly traffic volume and the emission factors. The source strength was computed for each of the pollutant as:

$$Q\ (g\text{-}km^{-1}hr^{-1}) = \sum (Ni\ (hr\text{-}1)\ x\ EFi\ \ (gm\text{-}1\ km\text{-}1)$$

Where Ni represents number of vehicles per hour of type i, EF represents emission factor for corresponding vehicle type. The emission factors used are chosen from studies conducted by CPCB (India), Vehicles were classified into four categories namely: two wheelers, three wheelers, four wheelers and heavy duty vehicles.

7.19 Results and Discussion

The Results of Air pollutants from Vehicular Traffic as according to their Emission Potential

Table 7.1- Pollutants Emitted Factor considered in g/km

Sr.No	Vehicle Category	CO	NOx	SPM	PM10
1	Two Wheelers	1.0	0.19	0.05	0.10
2	Three Wheelers	1.4	1.28	0.20	0.20
3	Passenger Cars (Petrol)	1.2	0.20	0.03	0.10
4	Passenger Cars (Diesel)	0.8	0.50	0.07	1.00
5	Light Duty Vehicles	2.5	2.00	0.56	1.25
6	Heavy Duty Vehicles	3.0	6.30	0.28	2.00
7	Buses	4.8	12.00	0.56	1.5

Calculated for the peak hours of the day in the office hours for the street on Typical Wednesday (29/04/2015) Calculations converted into the Vehicles/Hour. Background concentration is taken from IITM's Monitoring station in Bharati Vidyapeeth For a stretch of 100m Precise location Pune-Satara road, Balaji Nagar, Pune shown on the Map on Figure 7.14

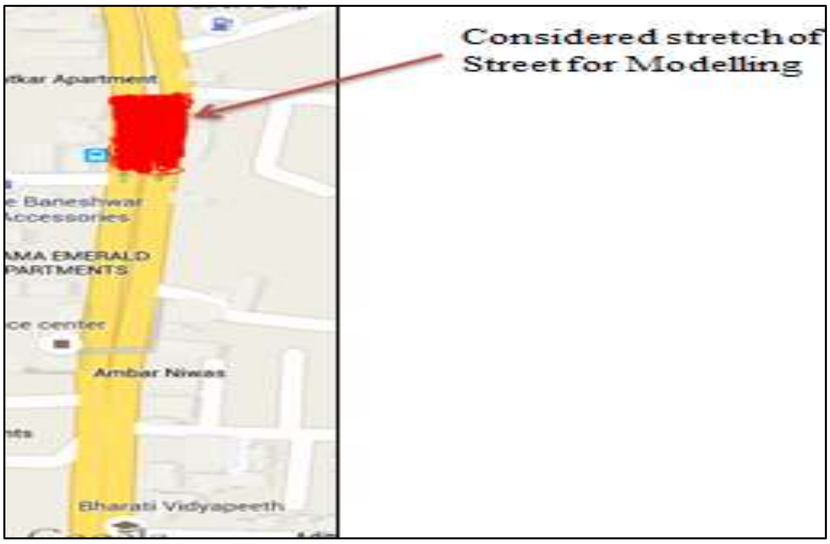
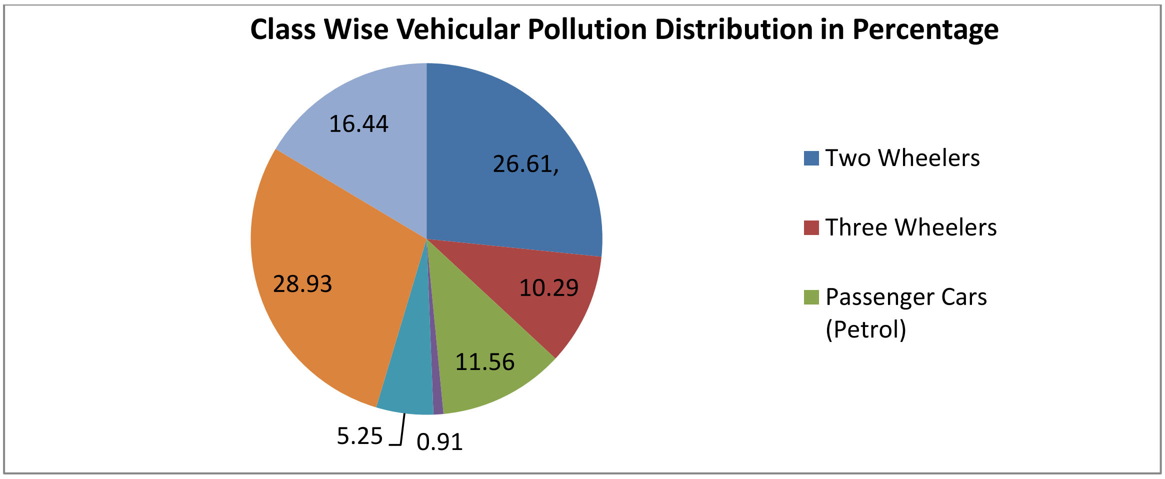


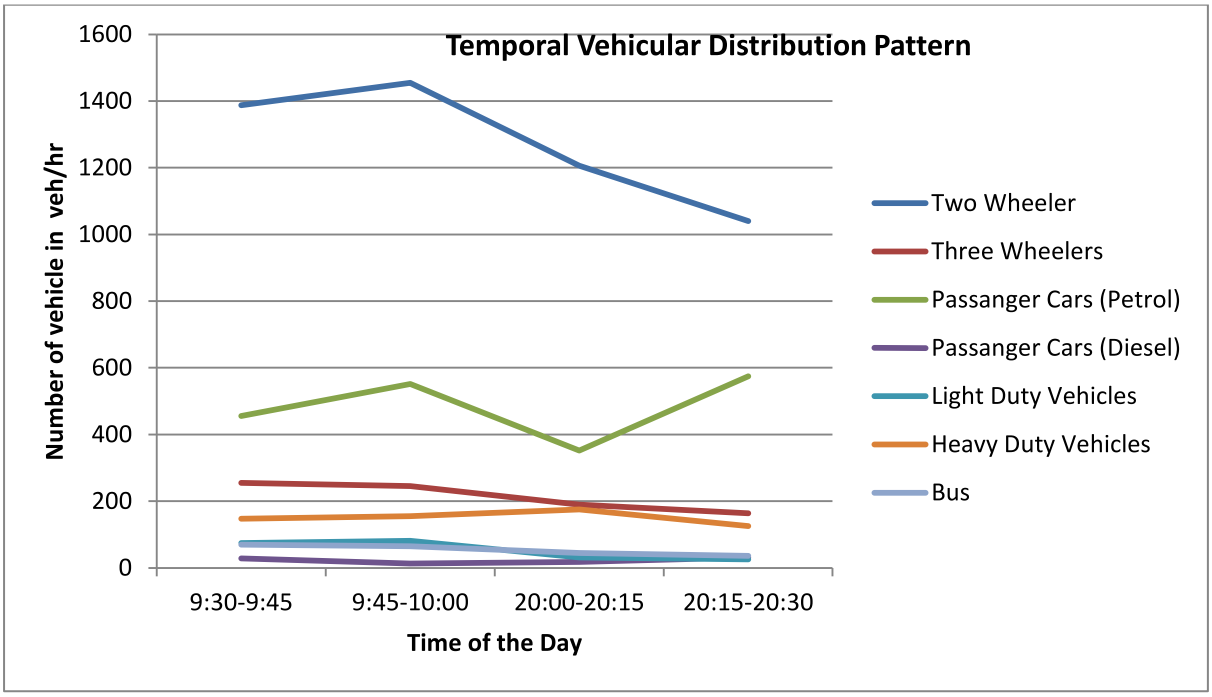
Figure 7.14 – Street Considered for Modelling on Google Maps

Table 7.2 – Vehicular traffic flow/hour at different timing

Timings	Two Wheeler	Three Wheelers	Passenger Cars (Petrol)	Passenger Cars (Diesel)	Light Duty Vehicles	Heavy Duty Vehicles	Bus
9:30-9:45	1387	255	455	28	74	147	70
9:45-10:00	1455	245	551	13	81	155	65
20:00-20:15	1206	190	352	18	31	175	45
20:15-20:30	1040	164	574	31	25	125	36



Graph 7.1 Class Wise Vehicular Pollution Distribution in Percentage



Graph 7.2 – Temporal Vehicular Distribution Pattern

Pune rightly said to be a 2-wheeler city in India with the number of 2-wheeler overwhelming. STREET Box model is developed by [99] This assumes a uniform concentration distribution over the street. It is very similar to Box model used for calculating the dispersion of pollutants generated from a city. The concentration in the street is determined from a mass flux balance between a horizontal convective flux, a turbulent diffusive vertical flux, and a continuous road transport emission source.

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Table 7.3 – Calculated Vehicular Emissions and Background Concentrations

Pollutants	CO	NOx	SPM	PM10
Average Vehicular Emissions	3011.075	2324.46	208.6175	725.2363
Background Concentration	0.71	12.25	153.25	210

Calculating Concentrations Using Box Model

Formula used

$$C = \frac{Q}{U_{ll} H/L * W + (D + lU_p)} \frac{W}{H} + C_b$$

Where,

C : Calculated concentration in the street(µg/m^3) C_b : Background Concentration(µg/m^3)

Q : Emission source strength (µg/m^3) H : Average building Height (m) = 11m, W : Width of street (m) = 8m, L : Length of the street (m) = 100m U_{ll} : Wind speed parallel to the street (m/s) = 1 m/s, U_p : Wind speed perpendicular to the street(m/s) =2.8 m/s l : Characteristic mixing length (m) = 1m, D : Diffusion coefficient at low wind speeds (m^2/s) = 1.5 m^2/s

Application of Box Model to the street of Katraj, Resultant pollutant concentrations are NOx are 19.77 µg/m^3.Like-wise we can calculate for other pollutants by this box model.

Pollutants	CO	NOx	SPM	PM10
Total Calculated concentration (µg/m^3)	4.602294	12.26454	164.4371	248.8908

7.20 Conclusion

STREET Box was used to simulate pollutant concentrations in the street. Nitrogen Oxide concentrations were modelled and monitored for a street canyon at Pune-Satara Road, Pune for a period peak hours in 1 day. From the results obtained it is clear that pollutant concentrations are dependent upon traffic volume, wind direction and wind speeds. Winds perpendicular to street axis are undesirable and produce worst conditions while winds parallel to street axis are favourable for pollutant dilution. The results obtained are compared with observations from measurement site. It was found that STREET Box model provides a good estimation of pollutant concentration. This may be due to less accuracy in background concentrations. These models can provide a quick estimate of pollutant concentrations which will be very useful in urban air quality assessment and to meet National Ambient Air Quality Standards (NAAQS).Overall pollutant concentration can be known in the street and if any measures to keep the pollution under check can be implemented.

7.21 Measures to Mitigate effect of Urban Heat Island

Components to be included in Urban Planning shall include

7.21.1 Necessity of Trees in the Urban Planning

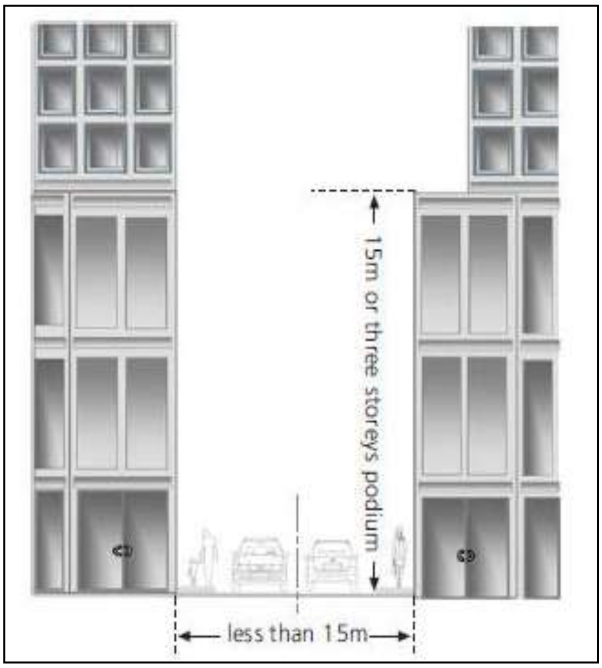
Trees have a cooling effect because of shade and the moisture transpired through leaf surfaces. Trees decline in numbers primarily through urban development, but equivalent amounts of trees are not replaced. Tree maintenance and protection ϒ Conservation and maintenance of existing trees are essential to avoid increased heat island effects over time. Tree planting ϒ Tree planting during development and redevelopment is critical to achieving a viable urban tree population. On-going public and private sector initiatives are needed, with active encouragement of planting by homeowners and property owners.

Maintenance and Protection of the existing Tree in the area .These typical condition are to modelled and Simulated each with respect to - air flow; the daily temperature variance ; thermal comfort to the pedestrians ; air quality at different times of the season; different aspect ratios of H/B,L/B, wind speed and direction, canyon geometry.[100]

[78] experimented with different street canyon geometry using Urban Canyon Models for analysis it was recommended by them for the city planners is that trees shall have smaller foliage as it will restrict the dispersion of air pollutants and as far as spacing is concerned it shall have sufficient spaces so as it enables atmospheric overflow and disperses the polluted air . Increasing vehicular traffic growth and emissions and their impact on human health and urban air quality there is an urgent need for a new pollution control regulatory framework for the management of vehicular traffic, air quality and emissions at all scales from local to global Air quality models can help to develop air quality management action plans and serves as an effective tool for improving air quality in urban centres. Air quality models predict the dispersion and dilution processes of the pollutants in the atmosphere using the emissions, prevailing meteorological conditions and street configurations to determine the ambient air concentrations [101].

The primary root of heat island in cities is due to the absorption of solar radiation by mass building structures, roads and other hard surfaces contained within the street canyon. The absorbed heat is subsequently re-radiated to the surroundings and increases ambient temperatures at night. To reduce the heat island effect it is advisable to use appropriate materials in order to improve the thermal characteristics of the urban environment. For example, light coloured surfaces are environmentally more beneficial as compared to dark coloured surfaces in urban areas.

This can be used to increase the awareness among urban planners, designers and decision makers on the importance of construction material choices which may be not only for aesthetic aspect but also for their effect on local climate and indirectly on energy consumption of buildings. To avoid negative impact of urban street canyon effect, planting of trees along the street may prove to be beneficial. Trees lined along the street become obstacles in the path of wind flow and dampen the air thus reducing the dispersion and number of pollutants in the canyon. Thus, by providing trees the atmospheric wind is able to intrude into the street canyon avoiding relevant concentration increases.



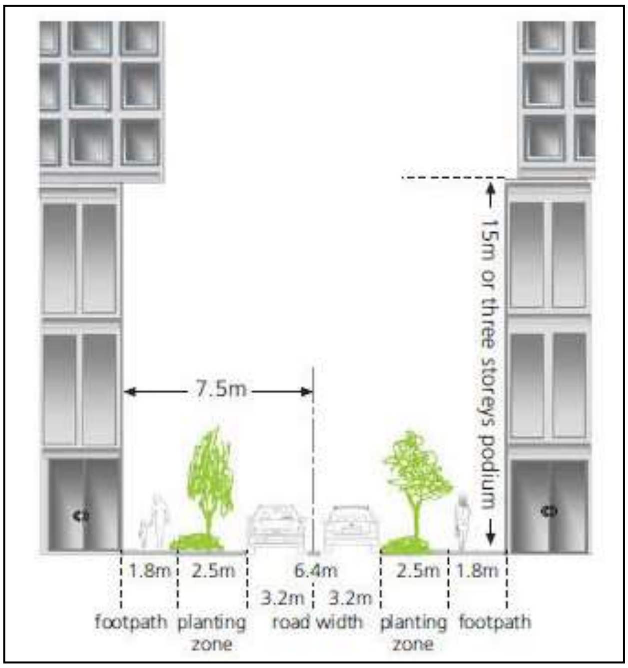


Figure 7.15 – Section of Street Canyon

The "Canyon" effect is created when tall buildings are abutting narrow streets which results in poor wind flow, high temperatures and poor environment quality.

Figure 7.16- Section of Street Canyon with trees

Building setback can improve the wind flow either through or around the building, enhance air quality in the neighbourhood and provide a better environment.

7.21.1.2 Using Cool Building Materials.

Rooftops comprise 20 to 25% of developed urban areas. Surface temperatures of reflective roofs are much cooler, reducing heat island effects. A wide range of rated cool roofing products are available that are cost effective measures for heat island.

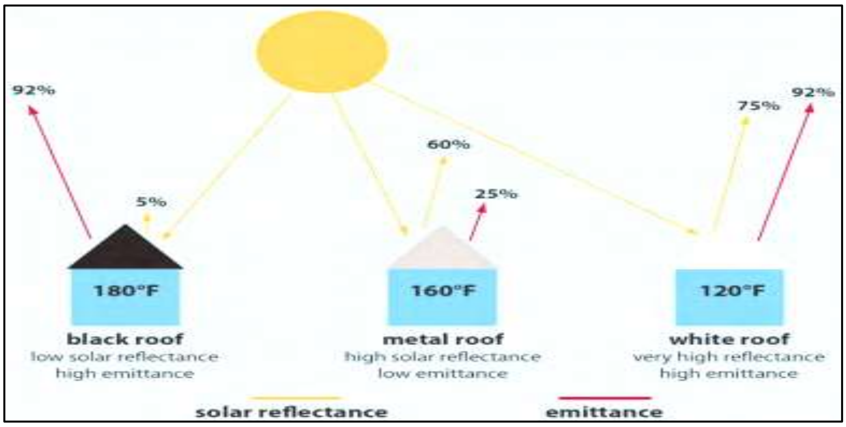


Figure 7.17– Effect of different Roofing on Reflectance and Emittance

On a hot ,sunny ,summer day ,a black roof that reflects 5% of the sun's energy and emits more than 90% of the heat it absorbs can reach 82^0C. A metal roof will reflect the majority of sun's energy while releasing about a fourth of the heat that it absorbs and can warm to 71^0C. A cool roof will reflect and emit the majority of the sun's energy and reach a peak temperature of 49^0C

In order to avoid the urban canyon effect, materials of surfaces that affect the environment in the canyon may be wisely chosen. Alternatives for a few examples of certain materials commonly used on building surfaces are mentioned in following point

a. Light coloured concrete may prove to be effective in reflecting up to 50% more light as compared to asphalt which will further reduce heat absorption eventually reducing the heat island effect.

b. In place of clay bricks wool bricks or mud bricks may be used in buildings because wool and mud bricks are sun-dried unlike clay bricks which are dried in kilns. Being sustainable in production these two types of bricks offer better sound absorption, higher thermal mass and are manufactured from natural resources.

c. Using coated glass or double glazed glass reduces the heat gain and loss into the building, keeping the surrounding environment of the building sustainable. In extremely hot climates solar control glass can be used which minimizes the solar heat gain and helps control glare. Glass may be a very good substitute instead of other opaque materials used on fenestrations of buildings since it helps control the exterior as well as the interior energy consumption of the building. Similarly many other building materials may have alternatives that may be used to keep the environment of urban canyons clear of dispersions and enhance the quality within them.

7.21.1.3 Buildings with Green Roofs

Green Roofs place vegetation on a roof assembly that includes a drainage system with a growing medium for plants[103]. Green roofs cool by (1) shading the roof surface and (2) through moisture evaporation from soils and plants. These roofs may be extensive systems, which are installed with a thin planting soil (4 to 6 inches), or intensive systems, with deeper soils and larger plants. Idealistic green Roofing is shown in Figure 7.18

Figure 7.18 – Idealistic Green Roofing in the city

7.21.1.4 Porous Paving

There are many types of porous or pervious paving, including pervious concrete and porous asphalt .These pavements cool by evaporation of water in the pavement, convective airflow, and reduced thermal storage. They are primarily used for non-road surfaces, although they are capable of higher traffic loads. Stormwater management and design features are key attributes for considering porous paving. Example is shown in Figure 7.19

Figure 7.19– Porous Paving in the City

7.21.2 Air Quality Management Plan for the City

The ultimate goal of any clean air policy is to develop strategies to reduce the risk of adverse effects on human health and the environment as a whole caused by ambient air pollution. With the existence of very susceptible populations and the ability to detect effects even if they are infrequent, we may be confronted with situations when the concept of thresholds is no longer useful in setting standards to protect public health. The principle of eliminating adverse effects with an adequate margin of safety even for the most susceptible groups may not be realistic. However, risk reduction strategies are and will continue to be powerful tools in promoting public health. The development of such strategies requires not only qualitative, but also quantitative knowledge on the most relevant adverse effects.

Pune is a city in which vehicles and industries both contribute almost equally. Therefore management strategies should focus upon both the sectors. Some of the city specific key strategies can be as follows.

- Introduction of CNG in vehicular and natural gas in industrial sector can reduce the SPM emissions substantially. Notification of vehicles norms like Bharat-II, III, IV. Phasing out of 10-year old commercial or all the vehicles .Checking fuel adulteration.
- In non-CNG scenario, supply of better quality of diesel and petrol.
- Proper inventorisation of industrial emission loads. Shifting of industries to the outskirts of the city. Round the clock vigilance of industries online monitors to be providing giving government agency Major augmentation of public transport system is required. Mass Rapid Transport system may be considered for the fast expanding and major urban areas in the country.
- Development of comprehensive air quality management plans based on scientific studies that involve information related to urban planning, ambient air quality, emission inventory, and air quality models. Systematically planned emission load mapping studies should be undertaken at regular intervals. Development of emission factors for Indian conditions to be expedited.
- Strengthening of air quality monitoring network (both in terms of number of stations as well as parameters monitored, including air toxics)
- Development, maintenance and continuous updating of a credible database on air quality, noise levels, emission inventory, source apportionment, health effects. Proper siting of projects to minimize the adverse impact on people and environment

- Non-point sources of pollution (such as generator sets, waste burning, etc) also need to be controlled . Promoting use of cleaner fuels like LPG and kerosene for domestic consumption like cooking for reducing indoor air pollution . Incentives for breakthrough environmentally benevolent substitutes, technologies and energy conservation
- Use of fiscal measures for pollution prevention and control. Economic instruments need to be in place to encourage a shift from curative to preventive measures, internalization of the cost of environmental degradation, and conservation of resources.
- Promotion of appropriate research and development (R & D) studies in areas such as Source Apportionment, Environmental Health, Exposure Assessment, Environmental Modelling etc.

7.21.3 Models for Better Planning of Urban Streets

Each city has its varied geographical, topographical, climatic characteristics it is important to study air Pollution Model pertaining to that city. Air quality limit values, whose objective is to protect public health, are frequently exceeded, particularly in busy urban streets and other hotspots in built-up areas. Evidence is continuously emerging related to the high risk of human exposure to increased pollutant concentrations in densely populated urban areas in contrast with the proven adverse effects on human health. It is, hence, imperative to fully understand the pollutants behaviour within confined urban surroundings in order to achieve further emissions abatement and improvements in urban air quality. This study presented the results of a limited monitoring and modelling methodology, which was adopted in order to understand the predominant mechanisms of pollution dispersion in an urban street canyon.

The dispersion modelling is also affected by a variety of parameters. The lack of accurate data related to street and roof level atmospheric conditions, the above mentioned shortcomings in the emissions calculation and the background pollution data are believed to influence mostly the model performance. The small aspect ratio of the street canyon, which may even prevent the formation of a primary wind vortex when the wind is perpendicular, the lack of knowledge related to the vehicle induced mixing and the thermal turbulence along the road are additional factors, which might predominantly affect the dispersion mechanism in the specific canyon, but it is not possible to be parameterised in the model.

CHAPTER 8
CONCLUSION AND RECOMMENDATIONS

8.1 Conclusions

Following Conclusions can be drawn from the Study on Urban Air Quality

1. Spatial Interpolation on GIS platform classifies the City on Basis of Air Pollution is necessary for identifying the Safe, Hazardous Zone.
2. Representation of Air Quality on GIS Maps Spatial and Temporal variation in the City is useful for Study purpose of Air Quality in the City.
3. Air Quality adversely affects the Human Health it causes harm to Respiratory, Immune system, Genetic systems, Cardiovascular systems.
4. The Lung function parameters for both Asthmatics and Non-Asthmatics have strong correction with the Air Quality.
5. The Particulate Pollutants such as $PM_{2.5}$, PM_{10} and Gaseous Pollutants like NOx, Ozone severely affects the Lung function of both Asthmatics and Non-Asthmatics.
6. Intense Outdoor activities such as Exercise, Jogging shall be restricted during high pollution days especially for Sensitive group of population like Children and Elderly.
7. Proper Design of Geometry of Urban Elements such as street width, street length and building height is necessary such that it won't prohibit the dispersion of air pollutant.
8. Air Quality Model is effective in determining the concentrations of a Street Canyon due to Vehicular Traffic.
9. Geography, Meteorology, Topography of a Microscale climate affects the air pollutant dispersion so the appropriate Air Quality Model is to be used, data availability is also an important factor for selecting Air Quality Model.

8.2 Recommendations

Following Recommendations can be made from the Study on Urban Air Quality

1. GIS Mapping shall be used as forefront technology in the visualizing the Air Pollution throughout the city for the government authorities to take action towards it.
2. Government alert systems on Air Quality levels is very essential, especially for the people having respiratory illnesses like Asthma, COPD to take precautions and they can control their activity accordingly.
3. City Authorities are to undertake strict rules to control the emissions in the transportation ,industries around the city.
4. An Urban Dweller shall perform Regular Pulmonary Function Test so that he can assess the impacts of Air pollution and be concerned of the Health shall include Anti-oxidants in his diet , Respiratory Masks when the pollution levels are high and use Air Purifiers to regulate Indoor Air Quality.
5. Urban Air Quality shall be one of the foremost issue a city planner shall consider in planning of City. Urban Planner are recommended to implement Porous Paving, Planting Trees, Cool Building Material, Green Roofs in their design to combat the Urban Heat Island Effect in cities.
6. Medical survey on larger basis of community health related disease shall be carried out for dissipation of knowledge of Harmful effects of Air Pollution amongst the masses especially for the sensitive groups like diseased,Children,Elderly.
7. Greater revised Emission Norms and Strict Environmental Impact Assessment (EIA) for industrialized areas around the cities to ensure minimal harm to the Air Quality of the City.
8. Despite the large number of Environmental Codes, there is still a need for scientifically sound, user-friendly and well-documented air quality models, as well as for high quality experimental data sets.

8.3 Scope of Future Research on the study

1. Future research on Urban Air Quality is expected to focus on topics related to low wind conditions, thermal effects due to solar radiation, microscale dispersion around fixed and moving obstacles, and pollutant dispersion in irregular canyons and other complex urban microenvironments like intersections, parking spaces.
2. The Proper understanding of the relation of Air pollution with Human Health requires in-depth knowledge of Pollutant Dynamics effect on Human Anatomy. We can then specify the Risks, Mechanism and Concentration by which the pollutant affects various systems in the human body. Adolescent Children (Age Range 10-18 years) are appropriate subject as it is the period of the lung growth. The effect of Ambient Air Pollutants on the lung development and a comparison of Polluted Areas to the Cleaner Areas .Here we shall also take into consideration the lifestyle, hereditary physiognomies
3. We propose are to research on Medical Institute are to conduct the test for a span of minimum of 5 years for the general population belonging to different age group residing in the same locality and linking the Air Quality Statistics to the Lung Function Test Results. Future studies should implement state-of-the art exposure assessment technologies aiming at individual level exposures to capture relevant exposures and limit confounding simultaneously.
4. More study are to done on the Economic aspect of effect of Air Pollution on Health the total cost of control measures should be measured in terms of total benefits to the society. The monetary benefits of reducing illness and premature mortality associated with a small change in air pollution exposure is important to estimate the value of unit reduction in each pollutant that can serve as an input for a cost-benefit analysis of air pollution mitigation programs. Besides, it helps in calculating the relative benefits from controlling one pollutant versus another pollutant.
5. The Indian government Agency like CPCB, SPCB's are to undertake this project of Urban Canyon Modelling for the future cities of India. Analysing Pollutant dispersion for a particular location through Urban Canyon Dispersion Model essential for the urban city planner as to how to tackle this increasing Urban Heat Island Effects in the city and a health risk to the urban dwellers as the natural dispersion,

wind flow, turbulence Innovative solutions are to be found out by a proper designing the Future cities in India such by the for this problem

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