# Relationship of Fine and Superfine Particulate Matter with Precursors and Meteorological Conditions at an Educational Institution in Delhi

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**Submitted by:**

**TINKIT GARG**
**(2K16/ENE/19)**

**Under the Supervision of**

**DR. RAJEEV KUMAR MISHRA**

**Assistant Professor**

**Department of Environmental Engineering**




**DEPARMENT OF ENVIRONMENTAL ENGINEERING**
**DELHI TECHNOLOGICAL UNIVERSITY**
**(FORMERLY DELHI COLLEGE OF ENGINEERING)**
**BAWANA ROAD, NEW DELHI - 110042**


**July, 2018**

**DELHI TECHNOLOGICAL UNIVERSITY**
(Formerly Delhi College of Engineering)
Bawana Road, Delhi-110042

# CANDIDATE'S DECLARATION

I Tinkit Garg, Roll No. 2K16/ENE/19 student of M.Tech Environmental Engineering, hereby declare that the project Dissertation titled **"Relationship of Fine and Superfine Particulate Matter with Precursors and Meteorological Conditions at an Educational Institution in Delhi"** which is submitted by me to the Department of Environmental Engineering, Delhi Technological University, Delhi in partial fulfilment of the requirement for the award of the degree of Master of Technology, is original and not copied from any source without proper citation. This work has not previously formed the basis for the award of any Degree, Diploma Associateship, Fellowship or other similar title or recognition.

Place: Delhi **TINKIT GARG**

Date: 31st July 2018

**DEPARTMENT OF ENVIRONMENTAL ENGINEERING**
DELHI TECHNOLOGICAL UNIVERSITY
(Formerly Delhi College of Engineering)
Bawana Road, Delhi-110042

# CERTIFICATE

This is to I hereby certify that the Project Dissertation titled, **"Relationship of Fine and Superfine Particulate Matter with Precursors and Meteorological Conditions at an Educational Institution in Delhi"** which is submitted by **TINKIT GARG**, Roll No. 2K16/ENE/19 (Department of Environmental Engineering), Delhi Technological University, Delhi in partial fulfilment of the requirement for the award of the Degree of Master of Technology, is a record of the project work carried out by the students under my supervision. To the best of my knowledge this work has not been submitted in part or full for any Degree or Diploma to this University or elsewhere.

Place: Delhi
Date: 31st July 2018

(**DR. RAJEEV KUMAR MISHRA**)
ASSISTANT PROFESSOR
SUPERVISOR

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**TINKIT GARG**
Roll No. 2K16/ENE/19
M. Tech (ENE)

# ABSTRACT

Traffic air pollution is a major concern in Delhi for health issues. The main cause of pollution in megacities like Delhi is due to large traffic exhausts and also due to the toxic wastes released by industries. Major pollutants mainly consist of particulate matter ($PM_{10}$, $PM_{2.5}$ and $PM_1$), nitrogen oxides ($NO_x$), sulphur dioxide ($SO_2$), carbon monoxide (CO) and ozone ($O_3$). Other reasons include change in weather patterns and climatic conditions with high or low wind speeds and mixing height which are responsible for air pollution and smog.

This study presents an analysis and interpretation of the variations of 6-hr daily averages concentration taken for 50 days for particulate matter ($PM_1$) measured at DTU Campus gate located at Shahbad Daulatpur near Bawana road, Delhi. The relationship of $PM_1$ with $PM_{2.5}$, $PM_{10}$ and precursor gases namely $NO_x$, CO, $O_3$ and with the meteorological parameters (RH and AT) shows the different variations in its values. $PM_{10}$, $PM_{2.5}$ and $PM_1$ are key polluting factors for Indian megacities. The location is of huge concern as one of the prestigious Universities in Delhi region is located nearby the road. As its location is just around the corner of North-West Delhi and also near to Bawana Industrial Area, so it becomes one of the roads which tends to receive heavy vehicles traffic during all day long due to which substantial amount of pollutants are released here into the environment.

In this work, it is tried to explain "Relationship of Fine and Superfine Particulate Matter with Precursors and Meteorological Conditions at an Educational Institution in Delhi". The selected location showed clear weekly, monthly or hourly variations at the monitoring site. The Particulate Matter data analysis showed average concentrations of PM ($PM_{10}$ = 220.70, $PM_{2.5}$ = 28.20, $PM_1$ = 19.8 μg/m3), lowest concentrations of PM ($PM_{10}$ = 11.0, $PM_{2.5}$ = 5.0, $PM_1$ = 0.8 μg/m3) and highest concentrations of PM ($PM_{10}$ = 1000, $PM_{2.5}$ = 265.0, $PM_1$ = 254.2 μg/m3) during the summer and pre-monsoon season.

Keywords: Particulate Matter; Precursor gases; Temperature; RH; $PM_{10}$; $PM_{2.5}$; $PM_1$; $NO_x$; CO and $O_3$.

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# LIST OF ABBREVIATIONS

| ABBREVIATIONS | MEANINGS |
|---|---|
| AT | Temperature |
| CFCs | Chloro-Fluoro-Carbons |
| CNG | Compressed Natural Gas |
| CO | Carbon Monoxide |
| CPCB | Central Pollution Control Board |
| CSE | Centre for Science and Environment |
| DPCC | Delhi Pollution Control Committee |
| DTU | Delhi Technological University |
| EPA | Environmental Protection Agency |
| EPI | Environmental Performance Index |
| GHGs | Green House Gases |
| IMD | India Meteorological Department |
| IPCC | Intergovernmental Panel on Climate Change |
| NAAQS | National Ambient Air Quality Standards |
| NCR | National Capital Region |
| NOx | Nitrogen Dioxide |
| O3 | Ozone |
| PAHs | Poly-cyclic Aromatic Hydrocarbons |
| PM | Particulate Matter |
| RH | Relative Humidity |

| | |
|---|---|
| SAFAR | System of Air Quality Forecasting and Research |
| SO2 | Sulphur Dioxide |
| SPSS | Statistical Package for the Social Science |
| TSP | Total Suspended Particles |
| UNEP | United Nations Environmental Program |
| VOCs | Volatile Organic Compounds |
| WHO | World Health Organisation |

# LIST OF SYMBOLS

| ABBREVIATIONS | MEANINGS |
|---|---|
| µg | microgram |
| µg/m³ | microgram per cubic meter |
| Ppm | parts per million |
| Ppmv | parts per million by volume |
| Ppb | parts per billion |
| Ppbv | parts per billion by volume |
| Nm | nanometer |

# CHAPTER - 1

# INTRODUCTION

## 1.1 Air Pollution Scenario

Air pollution remains a key environmental issue which originates in different forms, from clear dust particles or black carbon to invisible gaseous particles such as nitrogen oxides (NOx), volatile organic compounds (VOCs) and carbon monoxide (CO), and it can be created indoors and outdoors. Since some of the sources of environmental disruption are produced naturally, like the volcanoes or forest fires, while numerous of them are produced as a result of social activities at home or at workstation (Betancourt R. M., *et al.* 2017).

It has been a significant fear for the pre-modern era civilizations, with the burning of biomass and fossil fuels, affecting the human health as well as natural habitat of the surrounding environment. However, the growth of modern era /urban-industrialization lead to the change from fuelwood to coal and then to oil's, which in turn amplified the range of air contamination problems, drastically. Indeed, some injurious airborne toxins like chlorofluorocarbons (CFCs), various chemicals used in aerosol cans, refrigerators and air-conditioning systems depleting the ozone layer, didn't existed before the twentieth century.

## 1.2 Pre-Industrial Air Pollution

Indoor air pollution caused by cooking and heating with open fires in poorly ventilated residences became a major cause of illness in the earlier times. Logical investigations of tests of embalmed lung tissues from Egypt, Peru, Britain and somewhere else have uncovered that old social orders experienced anthracnosis, (darkening of the lungs), from long introduction to the harsh smoke of household fires. Smoke was probably persevered through inside as it kept the bugs, mosquitoes and different vermin away.

Due to the poor residential air quality with high concentrations of pollutants into the micro-environment without a doubt extended the threat of infection and decease from relentless respiratory contaminations. Though, demises from 'typical' diseases like bronchitis to date drew least attention from the medical department in the traditional period. In the creating scene, where cooking and heating with adulterated biomass, for

example, wood and creature compost stays normal, in 2004 around 1.6 million demises were associated with the indoor air contamination (Stephen Mosley, 2005).

Open air contamination just turned into a striking concern with the development of more urban areas. Early urban communities were altogether different in numerous regards from their cutting-edge partners. They were, for instance, conservative 'strolling urban communities', with the commercial centres, religious and open structures all being effectively available by walking. Since, when vast quantities of individuals swarmed into urban regions, smoke and different noxious exhausts from family units and small-sized industrial start-ups before long turned into a matter of worry.

Airborne toxication in India is a challenging issue with the significant sources being fuelwood and biomass consuming, fuel corruption, traffic congestion and vehicle exhausts. In harvest time and pre-winter season, a large scale burning of crop residue (also called as Stubble Burning) in agriculture fields (especially in areas of Haryana and Punjab) takes place by the farmers which acts as a major cause of smog formation (due to low mixing height) and PM emissions (Gokhale and Raokhande, 2008).

The per capita emissions of greenhouse gases (GHGs) in India is low but taking country as a whole is the 3$^{rd}$ largest polluter after United States and China (K. Anna and B. Anna, 2016). The Air (Prevention and Control of Pollution) Act was passed in 1981 to manage air contamination and there have been couple of upgrades in most recent 3 decades. Be that as it may, the 2018 Environmental Performance Index (EPI) ranked India at the bottom i.e. 177 out of 180 nations (CSE, 2018).

### 1.3 Fuel and Biomass Burning

The fuel used for cooking food in the rural areas of India is still prepared from fuelwood pieces, leaves, hay, a wet-mix of dry grass and mostly cow dung is used. And in this process of making food when burned, it produces enormous amounts of smoke emitting other harmful pollutants into the indoor air at higher concentrations even then coal.

Figure 1.1 Cow Dung formation

Low emission cooking fuels and even electricity are still not available in many rural parts of the country, due to which the lower class people have to survive with using all the material available for their survival. So no one cares what if it effects the environment or so. Therefore, biomass and highly contaminated fuel used for cooking & other purposes are the primary reason for smoke and permanent haze in the atmosphere of rural and urban areas.

Figure 1.2 Emission of pollutants from rural area using biomass and fuelwood as cooking fuel

India is the world's largest consumer of fuelwood, farming waste and biomass for energy or heating purposes. From the latest data across the country wide, India utilized 148.7 million tons coal substitution worth of fuelwood and biomass every year for domestic

energy supply to homes. India's national yearly per capita utilization of fuelwood, agricultural water and biomass was 206-kilogram coal proportionate (Devendra Pandey, 2013).

In 2010 rapports, with India's population expanding to around 1.2 billion, the nation burns more than 200 million tons of coal substitution worth of fuel wood and biomass consistently to meet its energy requirement for cooking and other household purposes. A survey analysis found out that the family units burn nearly 95 million tons of fuelwood, 33% of which were logs of wood and the rest were twigs. Twigs were mostly used in rural areas whereas, logs were more popular in the urban areas in India (Benaissa F., *et al.* 2018).

### 1.4 Superfine Particulate Matter ($PM_1$)

Generally Particulate Matter 1.0 ($PM_1$) particles are found in the air with very high concentrations and are released from various types of sources like; Automobiles, Industries, Factories Power Plants as an exhaust. Till today, no particular norms have been fixed for $PM_1$ standard concentrations neither by USEPA nor WHO or CPCB site (Verma M. K., et al. 2014).

But in the near future, the standards would be set for $PM_1$ and even smaller ultra-fine particulate matter with respect to the alarming pollution levels into the environment. So this study has been conducted to know the specific details about $PM_1$ concentrations into the atmosphere and its relationship with the precursor gases and also with meteorological parameters (Chen G., *et al*. 2018).

#### 1.4.1 Sources of $PM_1$

Particulate matter is emitted through various sources as follows:

Mechanical: crushing, cracking, powdering, transport of non-cohesive substances, soil erosion, etc. The size of these particles varies usually from a few microns to a few hundred microns in diameter (Pant P., et al. 2016).

Thermal or Chemical: These particles are formed by the evaporation followed by condensation which particularly changes the state of the material. The particle size ranges between few nanometres to under 1 µm.

Biological: bacteria, micro-organisms, fungi etc.

### 1.4.2 Formation of $PM_1$

The formation of particulates relies upon their source. Wind-blown mineral residue has a tendency to be made of mineral oxides and other material blown from the Earth's outside layer; this particulate is light-retaining (UNEP, 2001). Sea-salt is the second largest contributor in the world for spreading of airborne particles, it comprises primarily of sodium chloride created from sea spray; different constituents of environmental sea-salt reflects the structure of sea water, and consequently incorporate magnesium, sulphate, calcium, potassium, and so forth. Also, sea spray particle concentrates may contain natural mixes, which impact their chemistry (V. Perraud; E. Bruns; et al. 2012).

### 1.4.3 $PM_1$ Characteristics

Table 1. Classification of PM1 in Delhi NCR region

| Classification | Sub-sectors |
|---|---|
| 1 | Residential sector including:<br>• Combustion of heating appliances (boilers, inserts, closed and open fireplaces, stoves, etc.)<br>• Use of tobacco<br>• Non-road mobile machineries-Household and gardening |
| 2 | Diesel-fuelled passenger cars |
| 3 | Diesel-fuelled light duty vehicles |
| 4 | Ferrous metals production |
| 5 | Other agricultural sources (combustion plants and non-road mobile machinery) |

### 1.4.4 Transportation of $PM_1$

Road vehicles are by far the main contributors to air pollution in cities. PM transport practices and components in urban regions are impacted by numerous elements, for example, inflow conditions (wind direction, speed and turbulence), building geometry (stature, width, rooftop composition), encompassing building formats (road width and setup), thermal stratification (building and road warm capacitance), and vehicle traffic circumstances (vehicle discharges, vehicle speed and traffic volume) etc. (T. Chang, H. Kao, Y. Wu *et al.* 2009).

### 1.4.5 Health Effects due to $PM_1$

For the humans well-being, people have been aware of this situation regarding air pollution through pollutants for many psychological reasons, and protocols have been in existence from long times, though usually less dangerous than contamination by a large number of the vaporous mixes. This is clearly a broader view that will execute reliant on the chemical composition of the pollutants released also their dimensions (example: fine dust < 2.5 µm, asbestos threads and dirt, etc.). The part of PM emissions have been shown in specific problems of the breathing contraption, asthma assaults and the increasing amount of deaths from cardiovascular or respiratory ailments.

Particles with size greater than 10 µm or so, which are lightly visible to the naked eyes of a normal human-being are of less concern than smaller ones for the matter of health issues. Particles having diameter between 2.5-10 microns could reach the upper areas of the bronchial system inside the human body which may be thrown out by sneezing or coughing. The most harmful of all are those particles having size less than 2.5 microns and could be as small as in nano-meters also known as fine or ultra-fine particles. These particles could easily penetrate into the lungs or other critical organs inside the human chest and gets deposited (just like sedimentation of rocks takes place) into the blood stream and cause many infections to the whole body structure. These nano-sized particles could also carry with them toxic, allergic or carcinogenic composites, such as poly-cyclic aromatic hydrocarbons or heavy metals etc.

### Origin of Particulate Matter

Table 2. History of the NAAQS for Particulate Matter, from 1971 to 2012

| Final Rule/Decision | Primary/Secondary | Indicator | Averaging Time | Level | Form |
|---|---|---|---|---|---|
| 1971<br>36 FR 8186<br>Apr 30, 1971 | Primary | TSP | 24 hour | 260 µg/m³ | Not to be exceeded more than once per year |
| 1971<br>36 FR 8186<br>Apr 30, 1971 | Primary | TSP | Annual | 75 µg/m³ | Annual geometric mean |
| 1971<br>36 FR 8186<br>Apr 30, 1971 | Secondary | TSP | 24 hour | 150 µg/m³ | Not to be exceeded more than once per year |
| 1971<br>36 FR 8186<br>Apr 30, 1971 | Secondary | TSP | Annual | 60 µg/m³ | Annual geometric mean |
| 1987<br>52 FR 24634<br>Jul 1, 1987 | Primary and Secondary | $PM_{10}$ | 24 hour | 150 µg/m³ | Not to be exceeded more than once per year on average over a 3-year period |
| 1987<br>52 FR 24634<br>Jul 1, 1987 | Primary and Secondary | $PM_{10}$ | Annual | 50 µg/m³ | Annual arithmetic mean, averaged over 3 years |
| 1997<br>62 FR 38652<br>Jul 18, 1997 | Primary and Secondary | $PM_{2.5}$ | 24 hour | 65 µg/m³ | 98th percentile, averaged over 3 years |

| History of the NAAQS for Particulate Matter, from 1971 to 2012 | | | | | |
|---|---|---|---|---|---|
| **Final Rule/Decision** | **Primary/Secondary** | **Indicator** | **Averaging Time** | **Level** | **Form** |
| 1997<br>62 FR 38652<br>Jul 18, 1997 | Primary and Secondary | $PM_{2.5}$ | Annual | 15.0 $\mu g/m^3$ | Annual arithmetic mean, averaged over 3 years |
| 1997<br>62 FR 38652<br>Jul 18, 1997 | Primary and Secondary | $PM_{10}$ | 24 hour | 150 $\mu g/m^3$ | Initially promulgated 99th percentile, averaged over 3 years; (not to be exceeded more than once per year on average) |
| 1997<br>62 FR 38652<br>Jul 18, 1997 | Primary and Secondary | $PM_{10}$ | Annual | 50 $\mu g/m^3$ | Annual arithmetic mean, averaged over 3 years |
| 2006<br>71 FR 61144<br>Oct 17, 2006 | Primary and Secondary | $PM_{2.5}$ | 24 hour | 35 $\mu g/m^3$ | 98th percentile, averaged over 3 years |
| 2006<br>71 FR 61144<br>Oct 17, 2006 | Primary and Secondary | $PM_{2.5}$ | Annual | 15.0 $\mu g/m^3$ | Annual arithmetic mean, averaged over 3 years |
| 2006<br>71 FR 61144<br>Oct 17, 2006 | Primary and Secondary | $PM_{10}$ | 24 hour | 150 $\mu g/m^3$ | Not to be exceeded more than once per year on average over a 3-year period |
| 2012<br>78 FR 3085<br>Jan 15, 2013 | Primary | $PM_{2.5}$ | Annual | 12.0 $\mu g/m^3$ | Annual arithmetic mean, averaged over 3 years |
| 2012<br>78 FR 3085<br>Jan 15, 2013 | Secondary | $PM_{2.5}$ | Annual | 15.0 $\mu g/m^3$ | Annual arithmetic mean, averaged over 3 years |
| 2012<br>78 FR 3085<br>Jan 15, 2013 | Primary and Secondary | $PM_{2.5}$ | 24 hour | 35 $\mu g/m^3$ | 98th percentile, averaged over 3 years |
| 2012<br>78 FR 3085<br>Jan 15, 2013 | Primary and Secondary | $PM_{10}$ | 24 hour | 150 $\mu g/m^3$ | Not to be exceeded more than once per year on average over a 3-year period |

Source: Environmental Protection Agency (EPA) Evolution Chart

Note: Units of measurement for PM are micrograms per cubic meter ($\mu g/m^3$).

Delhi's radical street proportioning plan kicks in from the New Year as a frantic city battles to tidy up its squalid air. A lungful of air in Delhi is a toxic blend of smoke, residue, exhaust and slag with overwhelming convergences of synthetic substances, acids, metals and cancer-causing agents. What makes this "particulate matter" so dangerous is its size - the particles are sufficiently little to go through the nose and throat, and even enter tissue. The tiniest particles, which are 2.5 µm or less in width (namely: $PM_{2.5}$ and $PM_1$),

are the most exceedingly bad. They are more dangerous, travel more distant from their source and live somewhere down in lung tissue.

Despite the fact that Delhi's (and India's) air has become dynamically more terrible - a 2014 report states that air quality in the nation has declined 100 percent in the most recent years - contributions from various toxins have moved throughout the years.

### 1.5 Effects of Pollution changes

In the recent times, the Delhi government had approved a few processes for declining the pollutant exhausts from automobiles. They have introduced unleaded petrol as well as diesel along with CNG with low levels of sulphur which has resulted in reduction of sulphur dioxide ($SO_2$) emissions to a great extent and also a decrease in the levels of $PM_{10}$ particles, since the gas reacts with other molecules present into the atmosphere and converts into fine particulate matter ($PM_{10}$), therefore a small reduction in overall pollution levels in Delhi city.

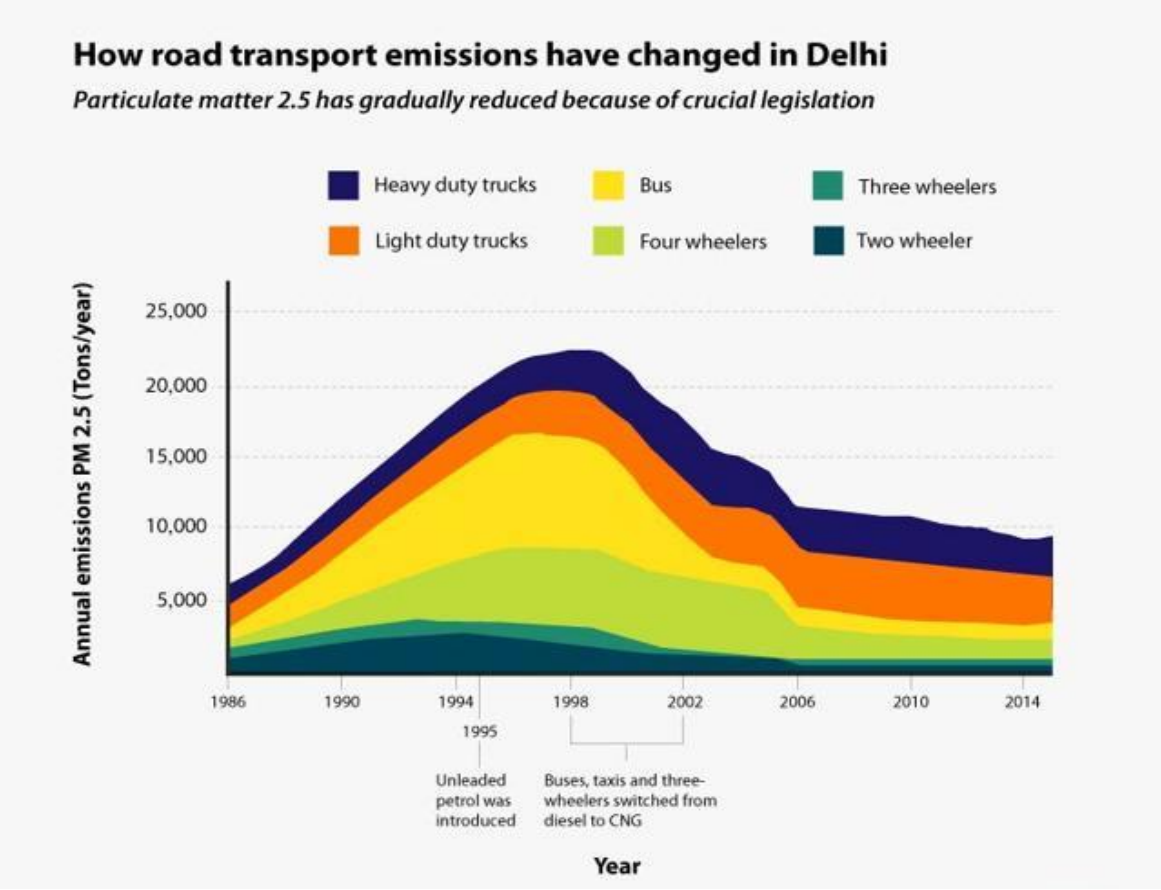


Figure 1.3 PM Emissions from Transportation Sector

## 1.6 Additional Culprits other than Vehicles

Road dust is a term which alludes to high convergence of metals, for example, Copper, Manganese, Nickel, Barium and Zinc etc. is a noteworthy reason for the increase in PM values in Delhi. It's the consequence of poor streets, overwhelming movement of traffic, unremitting development and various construction activities.

A similarly disturbing reason is Delhi's waste - consuming heaps of junk are a wellspring of particulate matter escalation, mercury and other unsafe synthetic substances. As per a few assessments, consuming waste creates almost 30% of the world's particulate matter production and 40% of its poly-cyclic aromatic hydrocarbons (PAHs), a class of synthetic compounds related with neurological illnesses, heart attacks and even cancer.

Air pollution occurs when any solid, liquid, or gaseous product, introduced into the atmosphere, harms the environment. As per the data provided by World Bank, 3 of the world's 20 cities having highest PM10 levels were in India, while 10 Indian cities had highest $PM_{2.5}$ levels across the globe.

Air pollution is a major problem which is increasing rapidly especially in megacities like Delhi. Atmospheric aerosols are a standout amongst the most essential and questionable factors in environmental change through their direct radiative driving and initiated cloud alterations (IPCC, 2013). Particulate matter, the strong and fluid particles in the air, is normally one of the key air contaminants and expands the likelihood of event of air pollution and fog events. Particulate contamination also causes adverse consequences for human well-being (Gao et al., 2015; Lim et al., 2012; Zhang et al., 2008) including respiratory and cardiovascular disease, excess mortality rate and shrinking life expectancy (Bagcchi S., 2015), and thus, reducing the pollutant levels in the environment definitely profits human health (Liu et al., 2018).

## 1.7 Air pollution in India

The Air (Prevention and Control of Pollution) Act was passed in 1981 to regulate air pollution and there have been some measurable improvements. However, the 2018 Environmental Performance Index ranked India $177^{th}$ out of 180 countries (EPI, 2018).

Figure 1.4 Vehicular traffic and exhausts Air Pollution in India

Note: The following figure shows the current view of the immense traffic problem emerged in Delhi. Traffic jamming on inadequate highway infrastructure is an everyday realism of India's megacities. More pollutants are emitted upto 4 to 8 times higher due to traffic jams and slow speeds with ignition ON vehicles than normal vehicles are generating (Amann M., *et al*. 2017).

Air contamination in India is a difficult issue with the real sources being fuelwood and biomass consuming, fuel debasement, traffic over-crowding and vehicle exhausts. In the post-monsoon and pre-winter season, large scale burning of crops known as stubble burning is done- a minimal effort other option to mechanical working - is a significant source of smoke, exhaust cloud and particulate contamination. India has low per capita discharges of ozone depleting substances yet the nation overall is the third biggest after China and the United States. A recent report on non-smokers has discovered that Indians have 30% lower lung working contrasted with Europeans (ENVIS, 2016).

**National Air Quality Index (AQI) India:**

- Good
- Moderate
- Unhealthy for Sensitive Groups
- Unhealthy
- Very Unhealthy
- Hazardous

| AQI | AIR POLLUTION LEVEL | HEALTH IMPLICATIONS |
|---|---|---|
| 0 - 50 | Good | Air quality is considered satisfactory, and air pollution poses little or no risk |
| 51 -100 | Moderate | Air quality is acceptable; however, for some pollutants there may be a moderate health concern for a very small number of people who are unusually sensitive to air pollution. |
| 101-150 | Unhealthy for Sensitive Groups | Members of sensitive groups may experience health effects. The general public is not likely to be affected. |
| 151-200 | Unhealthy | Everyone may begin to experience health effects; members of sensitive groups may experience more serious health effects |
| 201-300 | Very Unhealthy | Health warnings of emergency conditions. The entire population is more likely to be affected. |
| 300+ | Hazardous | Health alert: everyone may experience more serious health effects |

Figure 1.5 AQI India Values launched in New Delhi (2014), CPCB

### 1.8 Health Costs of Air Pollution

Presentation to particulate issue for quite a while can prompt respiratory and cardiovascular maladies, for example, asthma, bronchitis, lung growth and heart assaults. The Global Burden of Disease Study for 2010, distributed in 2013, had discovered that outside air contamination was the fifth-biggest executioner in India and around 620,000 early deaths happened from air contamination related maladies in 2010. As indicated by a WHO survey, 13 of the 20 most-dirtiest urban areas on the planet are in India; be that as it may, the precision and philosophy of the WHO ponder was addressed by the Government of India. Over a million Indians pass on rashly consistently because of air contamination, as indicated by the non-profit Health Effects Institute. More than two million kids - a large portion of the kids in Delhi have abnormalities in their lung function (Faridi S., et al. 2018).

# CHAPTER – 2

## LITERATURE REVIEW

### 2.1 Particulate Matter (PM) Pollution

PM stands for particulate matter (also called particle pollution): the term for a mixture of solid particles and liquid droplets found in the air. Some particles, such as dust, dirt, soot, or smoke, are large or dark enough to be seen with the naked eye. Others are so small they can only be detected using an electron microscope.

Most PM particles form in the atmosphere as a result of chemical reactions between pollutants.

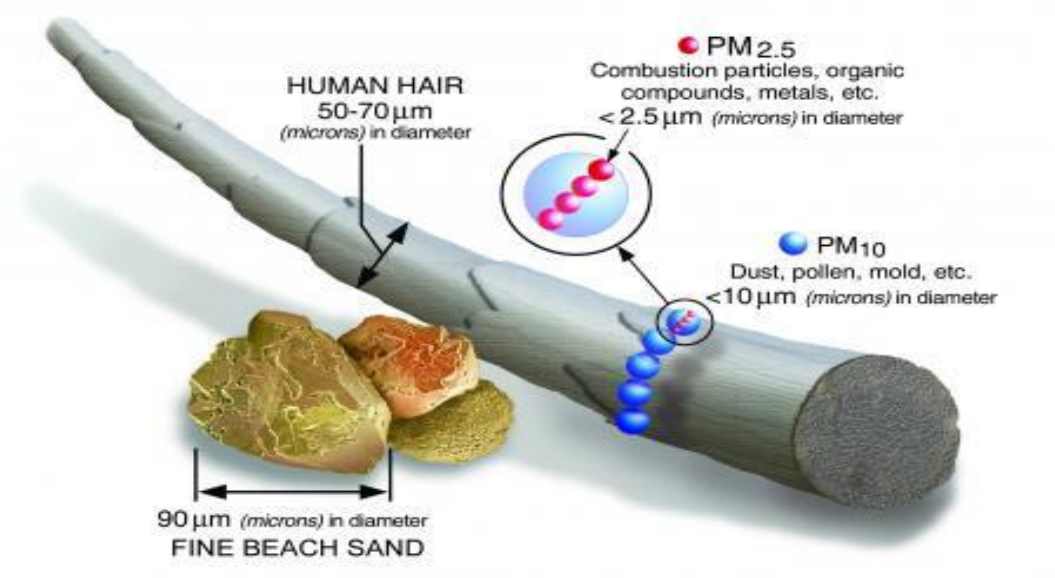


Figure 2.1 Particulate Matter Size Comparison

### 2.1.1 Sources of the Pollutant

Particulate matter (PM) is made up of very heterogeneous compounds in terms of chemical composition, solid or liquid state and size (characterized in particular by the diameter of the PM).

### 2.1.2 Sources of $PM_1$

- These particles come in many sizes and shapes and can be made up of hundreds of different chemicals.
- Some are emitted directly from a source, such as construction sites, unpaved roads, fields, smokestacks or fires.
- Most particles form in the atmosphere as a result of complex reactions of chemicals such as sulphur dioxide and nitrogen oxides, which are pollutants emitted from power plants, industries and automobiles.

Particulate pollution in urban atmosphere has been becoming a matter of concentration now a day. Different kind of natural as well as anthropogenic activities are contributing a large amount of particulate matter into ambient air. There are a number of research works are performed on particulate matter in several cities like Delhi, Kolkata, Raniganj-Asansol, Dhanbad- Jharia, Lucknow, Mumbai, Chennai, Visakhapatnam etc. in our nation as well as in abroad like in Taiyuan, Kathmandu , Guiyang, Dhaka, Pakistan and Italy etc. All these research works reflects that these particulate matters are comprised of trace amount of heavy metals like Pb, Cd, Cr, Mn and other inorganic ions like Na+, K+, F-, SO4 air pollutants are also found to be dependent on the prevailing meteorological condition. It is noticed that the atmospheric Pb is in decreasing trend now a day due to phase out of leaded gasoline in cities. Cd and Mn both are originated from mainly from industrial origin and transportation activities etc. However, a few mentionable works are as follows.

Kumar and Joseph (2006) had worked on PM2.5 and PM10 to understand the fine particle pollution in compliance with ambient air quality standards in Mumbai. The average PM2.5 concentration at ambient and at Kerb site was 43 and 69 µg/m3. The correlation coefficients between PM2.5 and PM10 at ambient and at Kerb site were 0.83 and 0.85 respectively thus indicating that most of the PM2.5 and PM10 were from similar sources. PM10 levels exceeded the central pollution control board standard during winter season.

Gupta et al. (2008) had dealt with air quality monitoring in an urban region of Kolkata, consisting of residential, commercial and industrial sites having high population density and pollution. Daily average PM10 concentrations exceeded quite a number of times the NAAQ standards. Approximately 85 % of the monitored PM10 data at residential area and 70 % at industrial area exceeded NAAQS. The observed daily average PM10

concentrations were 140.1 µg/m3 and 196.6 µg/m3, respectively at residential and industrial sites, while 8 h average concentrations of $PM_{10}$ at commercial site were 131.3 µg/$m^3$.

Giri et al. (2006) had measured the ambient particulate matter concentrations (PM10) at a network of six air monitoring stations in Kathmandu valley during the years, 2003 to 2005. The study revealed that particulate concentrations (PM10) measured were persistently higher at air sampling sites representing roadside areas compared to the background sites. The highest daily average PM10 mass concentration (633 µg/m3) for the study period was recorded at Putalisadak air monitoring station in the year 2005. Within the Kathmandu valley daily 24-h average PM10 ranged from 7 µg/m3 (Matsyagaon in the year 2004 and 2005) to 633 µg/m3 (Putalisadak in the year 2005). The lowest and highest average annual concentration during the study period was found 47.78 µg/m3 and 199.80 µg/m3 respectively at Matsyagaon and Putalisadak air-monitoring sites. It could be assumed that the difference in the observed concentrations can mostly be attributed to the traffic. Due to the rapid growth of industrial activities, population and traffic density, people in Kathmandu were facing serious air pollution problems.

A field study was carried out in central Italy on characterising atmospheric particulate matter ($PM_{10}$ and $PM_{2.5}$) from the point of view of the chemical composition by Perrino et al. (2007). An evaluation of the sources of PM and an identification of possible reliable tracers were obtained using a chemical fractionation procedure in their study. Total concentrations and speciation of metals had been studied in TSP of Guiyang by Wu et al. (2008) from April 2006 and January 2007 in PR China. The total average concentrations of five sites were found as 263 and 75.5 µg /$m^3$ for SPM and PM10 by Salam et al. (2008) in greater Dhaka.

Traffic-related air pollutants were monitored near major roads at 10 sites in Japan by Naser et al. (2009). Suspended particulate matter (100 % cut-off aerodynamic diameter at 10 mm), $PM_{2.5}$ (50 % cut-off aerodynamic diameter at 2.5 mm), and black carbon, from which elemental carbon (EC) content was calculated, were instantaneously and continuously monitored at four stations at various distances (about 5, 35, 70 and 150 m) from each of the target roads. They compared the observed concentrations with concentrations calculated by means of the conventional Gaussian plume model.

## 2.2 Gaseous Pollutants

The Clean Air Act does not require EPA to establish primary NAAQS at a zero-risk level, but rather at a level that reduces risk sufficiently so as to protect public health with an adequate margin of safety. In all NAAQS reviews, EPA gives particular attention to exposures and associated health risks for at-risk populations. Standards include consideration of providing protection for a representative sample of persons comprising at-risk populations rather than to the most susceptible single person in such groups. Even in areas that meet the current standards, individual members of at-risk populations may at times experience health effects related to air pollution (Cheng Y. H., *et al.* 2011).

Some of the air quality standards are designed to protect the public from adverse health effects that can occur after being exposed for a short time, such as hours to days. Other standards are designed to protect people from adverse health effects that are associated with long-term exposures (months to years). For example, the standard for ozone is based on pollutant concentrations measured over a short-term period of eight hours (Cheng Y., *et al.* 2011).

### 2.2.1 Nitrogen Dioxide ($NO_X$)

Nitric oxide (NO) and nitrogen dioxide (NO2) are emitted by cars, trucks, buses, power plants, and non-road engines and equipment. Emitted NO is rapidly oxidized into $NO_2$ in the atmosphere. Exposure to nitrogen dioxide has been associated with a variety of health effects, including respiratory symptoms, especially among asthmatic children, and respiratory-related emergency department visits and hospital admissions, particularly for children and older adults.

### 2.2.2 Carbon Monoxide (CO)

Gasoline-fuelled vehicles and other on-road and non-road mobile sources are the primary sources of carbon monoxide (CO) in the United States. Exposure to carbon monoxide reduces the capacity of the blood to carry oxygen, thereby decreasing the supply of oxygen to tissues and organs such as the heart. 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. For these people, short-term CO exposure further affects their body's already compromised ability

to respond to the increased oxygen demands of exercise or exertion. Thus people with angina or heart disease are identified as at greatest risk from ambient CO. Other potentially at-risk populations include those with chronic obstructive pulmonary disease, anaemia, diabetes, and those in prenatal or elderly life-stages.

### 2.2.3 Ozone ($O_3$)

Ground-level ozone forms through the reaction of pollutants emitted by industrial facilities, electric utilities, and motor vehicles; chemicals that are precursors to ozone formation can also be emitted by natural sources, particularly trees and other plants. Ground-level ozone can pose risks to human health, in contrast to the stratospheric ozone layer that protects the earth from harmful wavelengths of solar ultraviolet radiation. Short-term exposure to ground-level ozone can cause a variety of respiratory health effects, including inflammation of the lining of the lungs, reduced lung function, and respiratory symptoms such as cough, wheezing, chest pain, burning in the chest, and shortness of breath.

Ozone exposure can decrease the capacity to perform exercise. Exposure to ozone can also increase susceptibility to respiratory infection. Exposure to ambient concentrations of ozone has been associated with the aggravation of respiratory illnesses such as asthma, emphysema, and bronchitis, leading to increased use of medication, absences from school, doctor and emergency department visits, and hospital admissions. Oxides of nitrogen and CO mainly arise from automobile emissions while non methane hydrocarbons (NMHCs) are combustion generated. Depending on the Nitrous oxide (NO) concentrations, O3 may be produced or destroyed during oxidation of CO or no change occurs. The following reactions occur to give birth to surface ozone (Satsangi et al., 2004).

i. $CO + OH \rightarrow CO_2 + H$

$H + O_2 + M \rightarrow HO_2 + M$

$HO_2 + NO \rightarrow NO_2 + OH$

ii. $NO_2 + h\upsilon \xrightarrow{420nm} NO + O(^3P)$

$O(^3P) + O_2 + M \rightarrow O_3 + M$

iii. $OH + CH_3CH{=}CH_2 + O_2 + NO \rightarrow CH_3CHO + HCHO + NO_2 + OH \rightarrow O_3$

Thus in urban setting $O_3$ is formed from the catalytic reactions of $NO_x$ and VOCs (plus CO) all of which are emitted from vehicles and other combustion sources. $O_3$ is also the photochemical precursor of OH radicals, which control tropospheric chemistry.

### 2.2.4 Precursor Gaseous Pollutants ($NO_X$, CO and $O_3$)

A study on NOx at 19 traffic intersection points within the city of Kolkata was performed by Mondal et al. (2000). They observed significant seasonal variations with maximum concentration during winter and minimum during peak monsoon. The behaviour of oxides of nitrogen (NOx: NO, NO2) was observed by Lal and Patil (2001) in Mumbai. The monitoring results showed that at larger distance from the road the level of NO decreased but the concentration of $NO_2$ remained the same which was very harmful.

According to Ali and Athar (2008) the concentration of nitrogen dioxide was found in range of 0.02–0.08 ppm in Pakistan. The reason for high concentration of NO2 at this location could be the presence of large chemical manufacturing plant adjacent to the road. The nitrogen dioxide concentration at some sampling locations was higher than USEPA limit of 0.05 ppm, while at some location it was very well within limit of USEPA ambient air quality standards. Similarly the concentration of sulphur dioxide was found in the range of 0.02–0.07 ppm and concentrations at all the sampling locations were within limits of USEPA ambient air quality standards. The concentration of sulphur dioxide was found highest at a sampling point where it was in range of 0.05–0.07 ppm due to presence of industrial activity near the road. Traffic-related air pollutants like nitrogen oxides (NOx) were monitored near major roads at 10 sites in Japan by Naser et al. (2009).

Beig et al. (2007) observed surface ozone (O3) with its precursors namely, carbon monoxide (CO) and oxides of nitrogen (NOx) simultaneously on diurnal scale at Pune. According to their findings the maximum ozone reached as high as 85–90 ppbv during February, whereas minimum of 10- 15 ppbv was observed during the monsoon month of August. They revealed that a time lag of 5-7 hour was required for most of these precursor gases to photo chemically produce ozone to its maximum potential.

Carbon monoxide (CO), ozone ($O_3$) and black carbon (BC) aerosol mass concentrations were analysed from January–December, 2008 over tropical urban environment of Hyderabad. Higher concentration of BC, CO and ozone was observed during pre-monsoon, postmonsoon and winter and lowest concentrations exhibited during monsoon season (Badarinath et al., 2009).

Table 3. Summary for Literature Review

| Sr. No. | Author | Title | Year | Journal Published |
|---|---|---|---|---|
| 1. | Zhoua, G., Xua, J., Wei Gao, Yixuan Gu, Mao, Z and Linli Cui | Characteristics of $PM_1$ over Shanghai, relationships with precursors and meteorological variables and impacts on visibility. | 2018 | Atmospheric Environment |
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| 3. | Gongbo Chen, Lidia Morawska, Wenyi Zhang, Shanshan Li, et al. | Spatio-temporal variation of $PM_1$ pollution in China | 2018 | Atmospheric Environment |
| 4. | Sasan Faridi, Mansour Shamsipour, Michal Krzyzanowski, et al. | Long-term trends and health impact of $PM_{2.5}$ and $O_3$ in Tehran, Iran, 2006-2015. | 2018 | Environment International |
| 5. | Md. Aynul Bari, Warren B. Kindzierski | Characterization of air quality and sources of fine particulate matter ($PM_{2.5}$) in the City of Calgary, Canada Md. | 2018 | Atmospheric Pollution Research |
| 6. | R. Morales Betancourt, B. Galvis, S. Balachandran, J.P. Ramos-Bonilla, et al. | Exposure to fine particulate, black carbon, and particle number concentration in transportation micro-environments. | 2017 | Atmospheric Environment |
| 7. | Zhiyuan Li, Wenwei Che, H. Christopher Frey, Alexis K.H. Lau and Changqing Lin | Characterization of $PM_{2.5}$ exposure concentration in transport microenvironments using portable monitors. | 2017 | Environmental Pollution |
| 8. | S.K. Sharma and T.K. Mandal | Chemical composition of fine mode particulate matter ($PM_{2.5}$) in an urban area of Delhi, India and its source apportionment. | 2017 | Urban Climate |
| 9. | Pallavi Pant, Gazala Habib, Julian D. Marshall and Richard E. Peltier | $PM_{2.5}$ exposure in highly polluted cities: A case study from New Delhi, India. | 2017 | Environmental Research |
| 10. | Xiaolan Li, Yanjun Ma, Yangfeng Wang, Ningwei Liu and Ye Hong | Temporal and spatial analyses of particulate matter ($PM_{10}$ and $PM_{2.5}$) and its relationship with meteorological parameters over an urban city in North-East China. | 2017 | Atmospheric Research |

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|---|---|---|---|---|
| 11. | Prashant Kumar, Sunil Gulia, Roy M. Harrison and Mukesh Khare | The influence of odd-even car trial on fine and coarse particles in Delhi. | 2017 | Environmental Pollution |
| 12. | Yu Zhao, Xiaocheng Song, Yan Wang, Jianing Zhao and Kai Zhu | Seasonal patterns of $PM_{10}$, $PM_{2.5}$, and $PM_{1.0}$ concentrations in a naturally ventilated residential underground garage. | 2017 | Building and Environment |
| 13. | Qianqian Yang, Qiangqiang Yuan, Tongwen Li, Huanfeng Shen and Liangpei Zhang | The relationships between $PM_{2.5}$ and meteorological factors in China: Seasonal and regional variations. | 2016 | International Journal of Environmental Research and Public Health |
| 14. | Abhinav Pandey, Rajeev Kumar Mishra and Ankita Shukla | Study on air pollution trends (2010-2015) due to fireworks during Diwali festival in Delhi, India. | 2016 | Suan Sunandha Science and Technology Journal |
| 15. | Pallavi Pant, Sarath K. Guttikunda and Richard E. Peltier | Exposure to particulate matter in India: A synthesis of findings and future directions. | 2016 | Environmental Research |
| 16. | Priyanjali Gogikar and Bhishma Tyagi | Assessment of particulate matter variation during 2011-2015 over a tropical station Agra, India. | 2016 | Atmospheric Environment |
| 17. | Pallavi Pant, Anuradha S., Steven D. Kohl, Judith C. Chow, John G. Watson and Roy M. Harrison | Characterization of Ambient $PM_{2.5}$ at a Pollution Hotspot in New Delhi, India and Inference of Sources. | 2015 | Atmospheric Environment |
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| 19. | S. Tiwari, D.S. Bisht, A.K. Srivastava, A.S. Pipal, A. Taneja, M.K. Srivastava and S.D. Attri | Variability in atmospheric particulates and meteorological effects on their mass concentrations over Delhi, India. | 2014 | Atmospheric Research |
| 20. | Bilkis A. Begum, Philip K. Hopke and Andreas Markwitz | Air pollution by fine particulate matter in Bangladesh. | 2013 | Atmospheric Pollution Research |
| 21. | Mahmoud Mohammadyan and Bijan Shabankhani | Indoor $PM_1$, $PM_{2.5}$, $PM_{10}$ and outdoor $PM_{2.5}$ concentrations in primary schools in sari, Iran. | 2013 | Arhiv za Higijenu Rada i Toksikologiju |

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|---|---|---|---|---|
| 22. | Q. Yu, Y. Lu, S. Xiao, Shan S. Junxiu, L. Xun, M. Weichun, C. Limin | Commuters' exposure to $PM_1$ by common travel modes in Shanghai. | 2012 | Atmospheric Environment |
| 23. | S. Tiwari, D. Chate, A. Srivastava, D. Bisht, B. Padmanabhamurty | Assessments of $PM_1$, $PM_{2.5}$ and $PM_{10}$ concentrations in Delhi at different mean cycles. | 2012 | Geofizika |
| 24. | Owoade, O.K.; Olise, F.S.; Ogundele, L.T.; Fawole, O.G. and Olaniyi, H.B. | Correlation between particulate matter concentrations and meteorological parameters at a site in Ile-Ife, Nigeria. | 2012 | Ife Journal of Science |
| 25. | S. Tiwari, D. M. Chate, M. K. Srivastava, P. D. Safai, A. K. Srivastava and D. S. Bisht | Statistical evaluation of $PM_{10}$ and distribution of $PM_1$, $PM_{2.5}$, and $PM_{10}$ in ambient air due to extreme fireworks episodes (Deepawali festivals) in megacity Delhi. | 2012 | Natural Hazards and Earth System Sciences |
| 26. | D. Massey, A. Kulshrestha, J. Masih, A. Taneja | Seasonal trends of $PM_{10}$, $PM_{5.0}$, $PM_{2.5}$ & $PM_{1.0}$ in indoor and outdoor environments of residential homes located in North-Central India. | 2012 | Building and Environment |
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| 30. | Yu-Hsiang Cheng, Zhen-Shu Liu and Jhih-Wei Yan | Comparisons of $PM_{10}$, $PM_{2.5}$, Particle Number, and $CO_2$ Levels inside Metro Trains Traveling in Underground Tunnels and on Elevated Tracks. | 2012 | Aerosol and Air Quality Research |
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|---|---|---|---|---|
| 33. | K. Schafer, S. Emeis, S. Schrader *et al.* | A measurement based analysis of the spatial distribution, temporal variation and chemical composition of particulate matter in Munich and Augsburg. | 2011 | Meteorologische Zeitschrift |
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# CHAPTER – 3

## METHODOLOGY OF STUDY

### 3.1 Monitoring Site and Local Climatological Environments

Delhi, located between 28°21′17″ to 28°53′00″ scope and 76°20′37″ to 77°20′37″ longitude, is at around 160 km away in the South from the Southern side of Himalayas. The normal elevation of Delhi is 218 meters above mean ocean level while is limited by the Thar-Desert of Rajasthan in the West, fields of focal India in the South and Indo-Gangetic Plains (IGP) in the East. The megacity reaches out more than 1,484 $km^2$ geographical area with the present population reaching nearly 19 million till the end of 2017.

Delhi is the National capital territory of the country and furthermore a state for regulatory functions. It is one of the four megacities in current India. Delhi is situated at 28.61°N - 77.23°E coordinates which is the Northern part of India. It shares its boundaries with Haryana from the North side, and with Uttar Pradesh towards the Eastward side. It is the focal point of global legislative issues, occupation, culture, policy making and collected works in India.

The atmosphere of Delhi is semi-dry and is basically affected by its position and by the flow patterns of the wind direction throughout the year. India Meteorological Department (IMD), classifies Delhi into four categories according to the seasonal climate changes and weather patterns, namely; pre-monsoon or summer, monsoon, post-monsoon and winter season, respectively. Summer is to a great degree sweltering, with most extreme temperatures measuring between 45-48 °C. Dust storms from close-by Thar Desert are also affecting the climate of Delhi amid summers just before slight rains start to fall in the May - June period. During the pre-monsoon and as the rainy season starts relative humidity (RH) increases to a sudden span due to the variations between wind velocities and inversion conditions because of heavy rainfall (in the vicinity of 600 and 800 mm), whereas the air is dry amid whatever is left of the year.

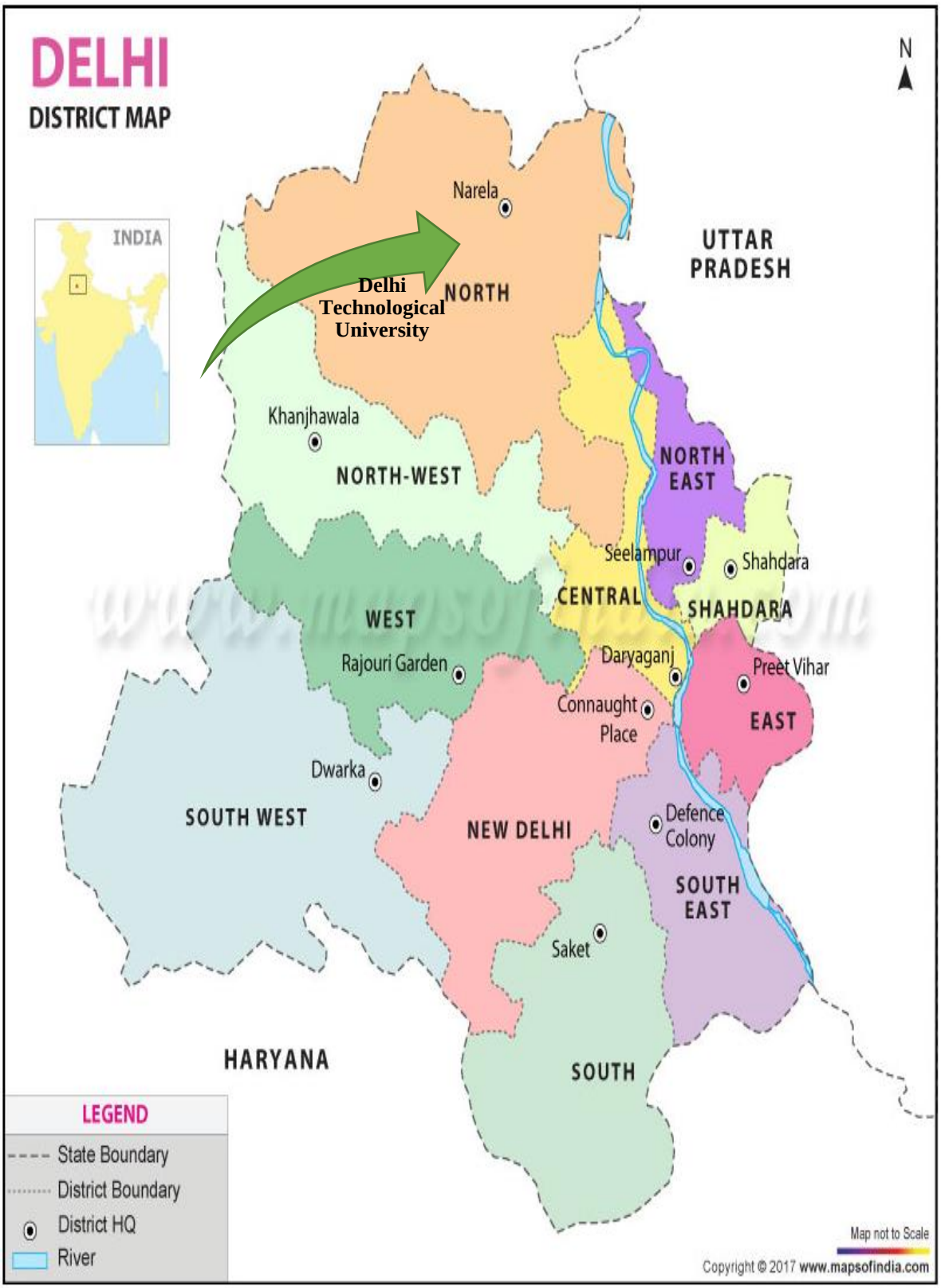


Figure 3.1 DTU, location in Map of Delhi

Delhi Technological University (DTU), earlier recognized as Delhi College of Engineering, is an Engineering University located at coordinates 28.7501° N - 77.1177° E (Shahbad Daulatpur, Main Bawana Road, Delhi - 110042) on the outskirts of North Delhi, India. It is one of the oldest engineering colleges in India and Delhi's foremost engineering college. DTU resides more than 8 thousand students and researchers from all over India and also NRI aspirants from various countries.


Figure 3.2 Monitoring Site (Main Entrance Gate of Delhi Technological University, Delhi)

The DTU area witnesses high vehicular traffic, including trucks entering and escaping the city. Garbage burning is also extensive in the area. According to Environment Pollution (Prevention & Control) Authority, this corner of the city has been consistently showing high pollution levels. There is a significant transformation in pollution levels in the internal and external vicinity of the main gate of DTU. The university campus is surrounded by extremely populated and over-crowded areas like Bawana industrial area, Samaypur, Shahbad and Badli, which are perhaps the most polluted neighbourhoods to breath in relation to air quality. Diverse pollutants emitted into the atmosphere near the monitoring site through various sources like automobiles, industries, power plants, factories, etc. pollute the environment which leads to harmful effects on the health of the residents residing therein with every minute of inhalation of the contaminated air.

### 3.2 Research and Methodology

Day-to-day averages of four pollutants i.e. $PM_1$, $NO_x$, CO and $O_3$ were monitored from the period of 1st June, 2018 to 20th July, 2018 using the primary instruments from Air and Noise Pollution Laboratory, Delhi Technological University at the monitoring site. 8-hr readings were taken on daily basis for the criteria pollutants and precursor gases.

Also secondary data was collected from the various government organizations (CPCB, DPCC, SAFAR) for $PM_{10}$ and $PM_{2.5}$, respectively and various meteorological data such as Relative Humidity, Ambient Temperature and Solar Radiation were also collected from govt. departments (India Meteorological Department) for the monitoring site.

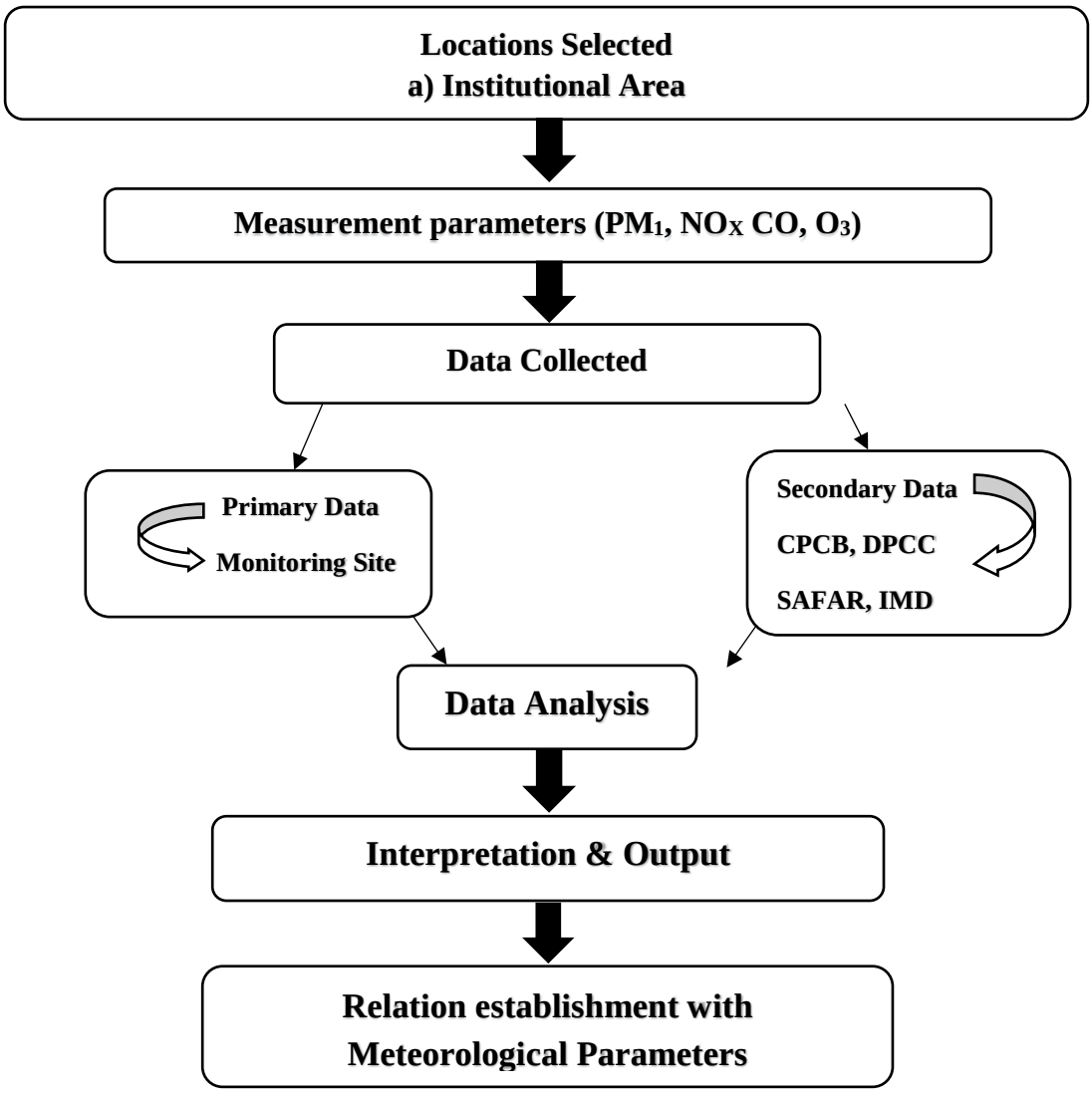


Figure 3.3 Flow Chart for Research and Methodology

### 3.3 Instrumentation

Various instruments used in the project work and their specifications:

#### i. SKC EPAM-5000 (Haz-Dust Sampler for $PM_1$)


Figure 3.4 EPAM-5000 Environmental Particulate Air Monitor

The SKC EPAM-5000 is a high affectability continuous particulate matter monitoring instrument intended for encompassing natural and indoor air quality applications. This unit consolidates conventional channel strategies with real-time data collection procedures. These techniques merged fulfils the restrictions of all other airborne particulates recording instruments (Figure 3.4).

Working Principle: The SKC EPAM-5000 uses the principle of near-forward light scattering of an infrared radiation to immediately and continuously measure the concentration in mg/m3 of airborne dust particles. This principle uses an infrared light source situated at a 90-degree angle from a photo detector.

It is a real-time air pollution data monitoring device. Dust particles are drawn into the sensor head and are identified once consistently i.e. every 1 sec, 10 sec, 1 min etc. depending on the time span applied during setting up the instrument. The dust deposits are immediately computed and shown on the display of the LCD monitor. All the readings of the set parameter are recorded and stored as a file in the instrument memory and can be accessed anytime using the software provided with the instrument and also the 9-pin

RS232 cable which can be connected to PC having the software pre-installed into it to download the stored data.

### ii. Ambient CO Monitor (APMA-370, HORIBA)

APMA-370 is an ambient carbon monoxide (CO) monitor using the non-dispersive infrared analysis method as its operating principle (Figure 3.5). This monitor allows you to continuously measure the concentrations of CO in the atmosphere.


Figure 3.5 Ambient CO Monitor APMA-370

APMA-370 is a standalone system that allows you to operate it by merely supplying calibration gas. The system can be upgraded by connecting a computer, monitor, recorder, multi-gas calibrator.

The system configuration of APMA-370 is shown in the following diagram:

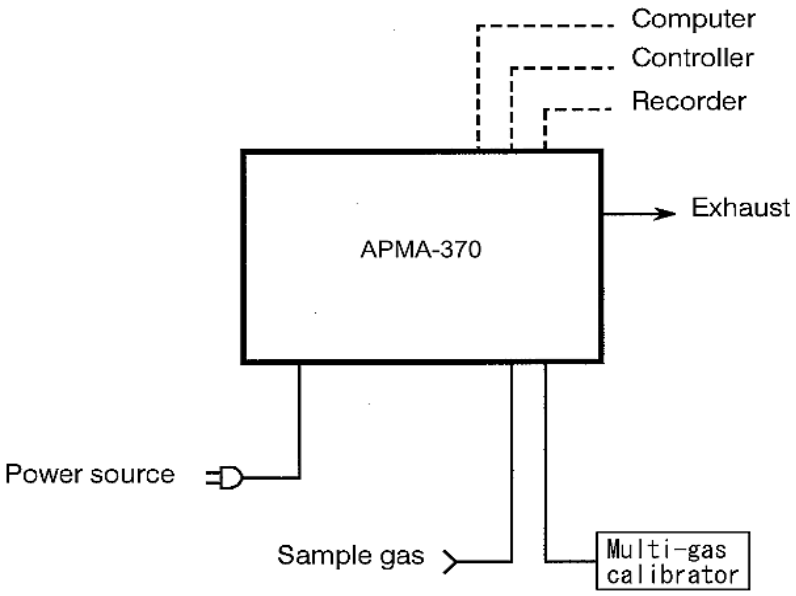


Figure 3.6 APMA-370 System Configuration

### iii. $NO_x/NO/NO_2$ Analyzer (2B Technologies)

The NOx monitor/analyser can be used for the direct measurement of atmospheric nitrogen oxides ($NO_x$) including both NO and $NO_2$ with a concentration measurement within the range of 0 to 10,000 ppb for $NO_2$ and 0 to 2,000 ppb for NO with high accuracy and precise data (Figure 3.7)


Figure 3.7 $NO_X/NO/NO_2$ Analyzer – 2B Technologies

Working Principle: The nitrogen oxides ($NO_x/NO/NO_2$) analyzer/monitor is similar to the ozone monitor. This instrument measures the values for $NO_x/NO/NO_2$ with great precision and uses the principal of absorbance at 405 nm using a miniature White cell.The concentration of $NO_2$ particles is calculated using the Beer Lambert's Law, whose equation is given below:

$$[NO_2] = \frac{1}{L\sigma} \ln\left(\frac{Io}{I}\right)$$

The $NO_2$ monitor has a sample flow rate of approximately 1.5 L/min. The sampler does not requires any type of external calibration, it has its own absolute method of calibrating the instrument. In this device also the data Logging function should be turned ON for the readings to be save within the device storage and it need to be extracted on to a computer using the appropriate software for the collection of instrument data.

### iv. Ozone Monitor Dual Beam (2B Technologies)

The Dual Beam Ozone ($O_3$) Analyzer invented by the 2B-Technologies is a portable and handy device built for measuring and storing the real-time ozone concentrations at different time spans (for as low as 2 seconds and going upto 1-hr). This instrument assists in calculating accurate results of atmospheric ozone over a wide range of detection limit from 1 ppbv to an upper limit of 100 ppmv based on the process of absorption of

ultraviolet light at 254 nm. The concentration of ozone particles is calculated for each cell using the Beer Lambert's Law whose equation is given below:

$$C_{O_3} = \frac{1}{\sigma l} \ln\left(\frac{lo}{l}\right)$$


Figure 3.8 Ozone ($O_3$) Analyzer – 2B Technologies

Working Principle: Ozone is measured based on the attenuation of light passing through two separate 15-cm long absorption cells fitted with quartz windows. The operation of the Ozone analyzer is simple and it requires external power supply or a 12V battery can be used for field testing.

When the instrument is switched ON it will display the version of the instrument followed by displaying the date and time. It take a few seconds to start and show the readings for Ozone ($O_3$) as well as cell temperature and pressure. First couple of readings will show some huge positive and negative fluctuates, then after the machine warms up the accurate results are displayed on the screen. The instrument takes 15-20 minutes to stabilize itself and its components (the lamp, absorption cell and photodiode) to display accurate readings.

The data logger need to be turned ON to save the samples taken at the site. But it has a limitation that the device can store upto a certain Log values (16,383 lines) for the time interval fixed. Once the Logger input is full than no further readings could be stored and this could result in major data loss if the instrument is run for a longer duration. So, it is better to make a backup in every 2-3 days of using the instrument or better to use an external data card. The flow rate in this instrument is quite nominal approximately 1.8 Litre/min.

# CHAPTER – 4

## RESULTS AND DISCUSSION

### 4.1 Meteorological Study and Climatic Conditions

Meteorological conditions plays a pivotal role as the hourly concentration change and it has a have strong impact on the seasonal changes which may be concealed by the prevailing meteorological conditions and offers incorrect data or inappropriate analysis. Delhi is situated on the banks of river Yamuna with Himalayas being in the north. The climate of Delhi has high variations between summer and winter temperatures and precipitation, while Delhi remains hot and humid during most of the year and the climate turns out to be very hot throughout the month of June after which pre-monsoon occurs in the month of July and then followed by monsoon occurring somewhere between July-September. Winters are very chilly which peaks in at the start of November and continues till the month of February.

### 4.2 Meteorological Parameters

Meteorological factors play a crucial role in determining the role of pollutant concentrations and levels. Different pollutants behave differently with change in climatic conditions such as Wind Direction, Wind Speed, Mixing Height, Temperature, Relative Humidity etc. The present study takes into account Ambient Temperature and Relative Humidity (from IMD) into account for building a relationship between the Criteria Pollutant ($PM_1$) and precursor gases ($NO_x$, CO and $O_3$).

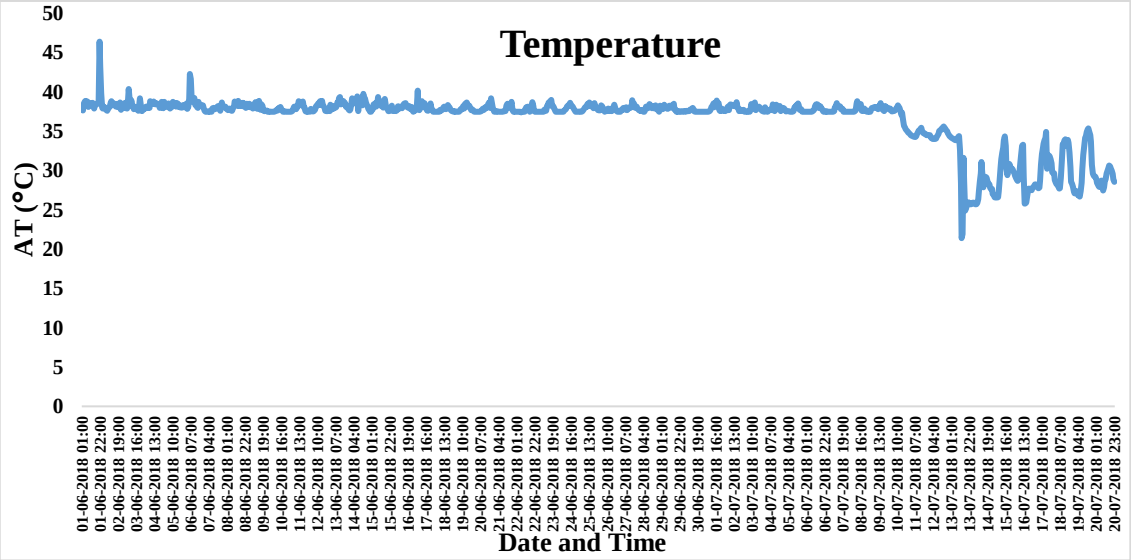


Figure 4.1 Graph for Temperature Variations throughout June-July, 2018

The monthly average mixing height for the months of June-July was found to be 785 meters for the monitoring site. The range for daily average mixing height was observed from 398 meters to 942 meters. Daily average wind speed was observed in the range of 1.7 m/s - 4.5 m/s. The average temperature for the month of June to July was measured to be around 36.5°C.

Relative humidity relates to the amount of water vapour present in the air. RH depends upon the temperature and pressure of the surrounding environment. The average relative humidity around the monitoring site was found to be 52.35% with respect to temperature and atmospheric pressure. Maximum and minimum values for RH in the month of June and July were found to be 98.10% and 10.08%, respectively.

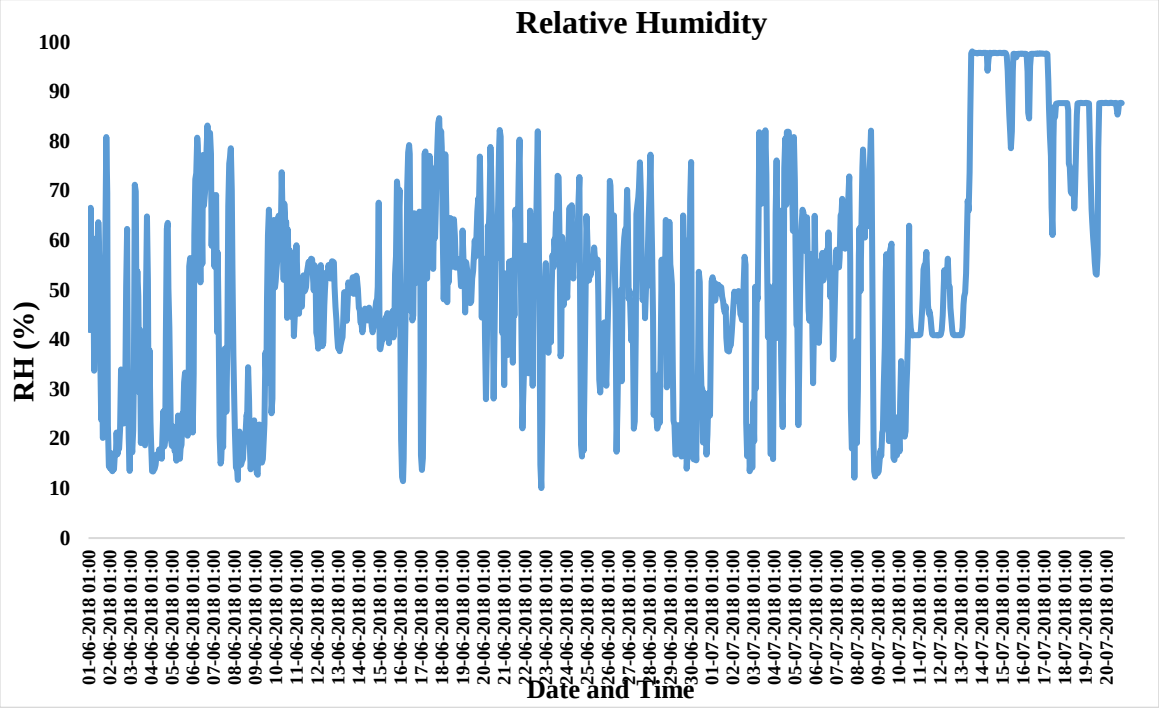


Figure 4.2 Graphical representation of RH in DTU Area

The precursors namely; Nitrogen Oxide ($NO_x$), Carbon Monoxide (CO) and Ozone ($O_3$) were found under their respective NAAQS standards for 24 hours' time interval for the monitored location as shown in figure 4.3 below. The average, maximum and minimum values for the precursor gases in the time duration were calculated and noted down. The averages of NOx, CO and $O_3$ were 20.5 (ppb), 9.6 µg/m³ and 466.4 µg/m³, respectively. Moreover the maximum values obtained were seen to be 44.30 (ppb), 187.9 µg/m³ and 2620 µg/m³ for the precursor gases. Likewise, the minimum values of $NO_X$, CO and $O_3$ were as follows: 13 ppb, 50 µg/m³ and 6.4 µg/m³, respectively.

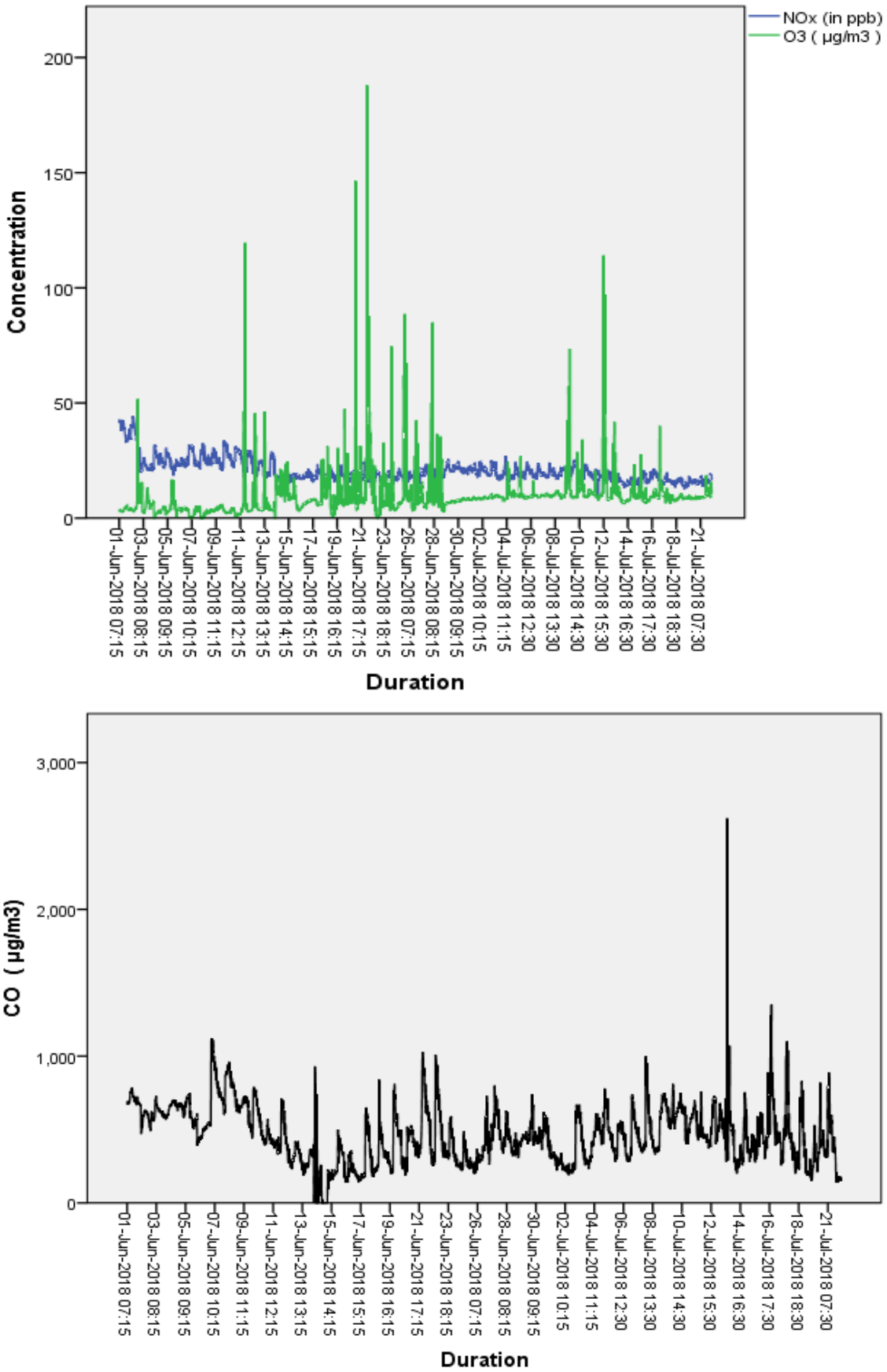


Figure 4.3 Graphical representation of $NO_X$, CO and $O_3$ at the monitoring site.

The micro-climatic conditions of DTU, Delhi are shown in Table 4. Whereas the maximum mixing height of pollutants was 942 meters, whereas the maximum values of wind speed and temperature observed were 4.5 m/sec and 42.6°C, respectively.

Table 4. Monthly Range and Average for Metrological Parameters in Delhi, June (2018)

| **Parameters (Unit)** | **AVERAGE** | **MAX** | **MIN** |
|---|---|---|---|
| Mixing Height (m) | 785 | 942 | 398 |
| Wind Speed (m/s) | 3.4 | 4.5 | 1.7 |
| Temperature (°C) | 36.5 | 42.6 | 29.3 |
| Relative Humidity (%) | 52.35 | 98.10 | 10.08 |

Source: CPCB, 2018

### 4.3 $PM_1$ Relationship with $PM_{2.5}$ and $PM_{10}$

$PM_1$ readings were calculated for the monitoring site using the SKC-EPAM 5000 Haz Dust Sampler instrument for continuously 51 days during summer and pre-monsoon period (between 1st June to 21st July, 2018). Daily values were recorded for the emission parameters of the pollutants. Different time period were set for better accuracy of results. Time period taken in the instrument are as follows: 10 seconds, 1 minute, 15 minutes, 1 hour, 4 hour and 8 hours readings were taken via the sampler, respectively.

The other values for $PM_{2.5}$ and $PM_{10}$ were taken from various government portals like CPCB, DPCC and SAFAR which provide 24-hourly real-time data for the pollution parameters. The meteorological parameter values for RH, Temperature and Solar Radiation were taken from IMD, India.

The following graph shows the relationship of $PM_1$ with $PM_{2.5}$ and $PM_{10}$ concentrations. In this data the readings for $PM_1$ have been monitored for 6-hrs daily at different time intervals at the monitoring site with the help of real-time ambient air quality measurement instruments (EPAM-5000) and the data for $PM_{2.5}$ and $PM_{10}$ have been collected from the CPCB (NAAQMS) monitoring station near the monitoring site. The readings explain that $PM_1$ is far less as compared to $PM_{10}$ and fluctuates in comparison with $PM_{2.5}$ sometimes in the summers and pre-winter due to high temperature and higher relative humidity.

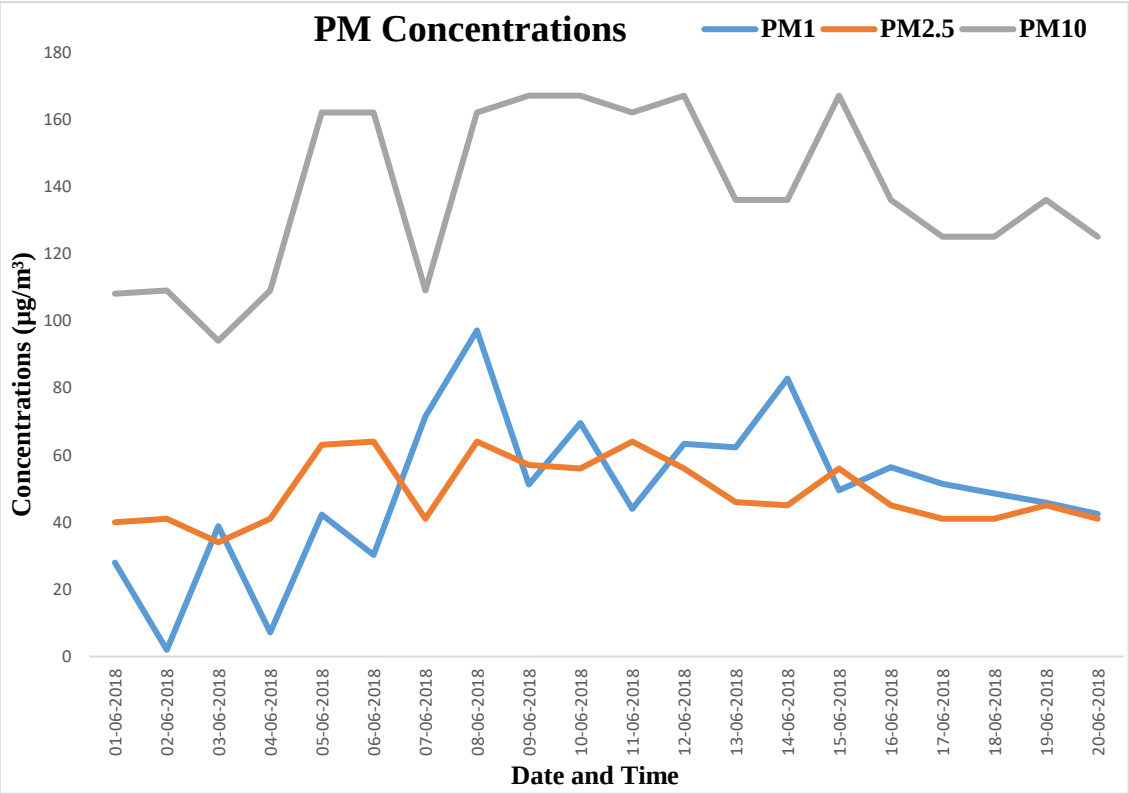


Figure 4.4 $PM_1$, $PM_{2.5}$, $PM_{10}$ Concentrations at DTU Gate

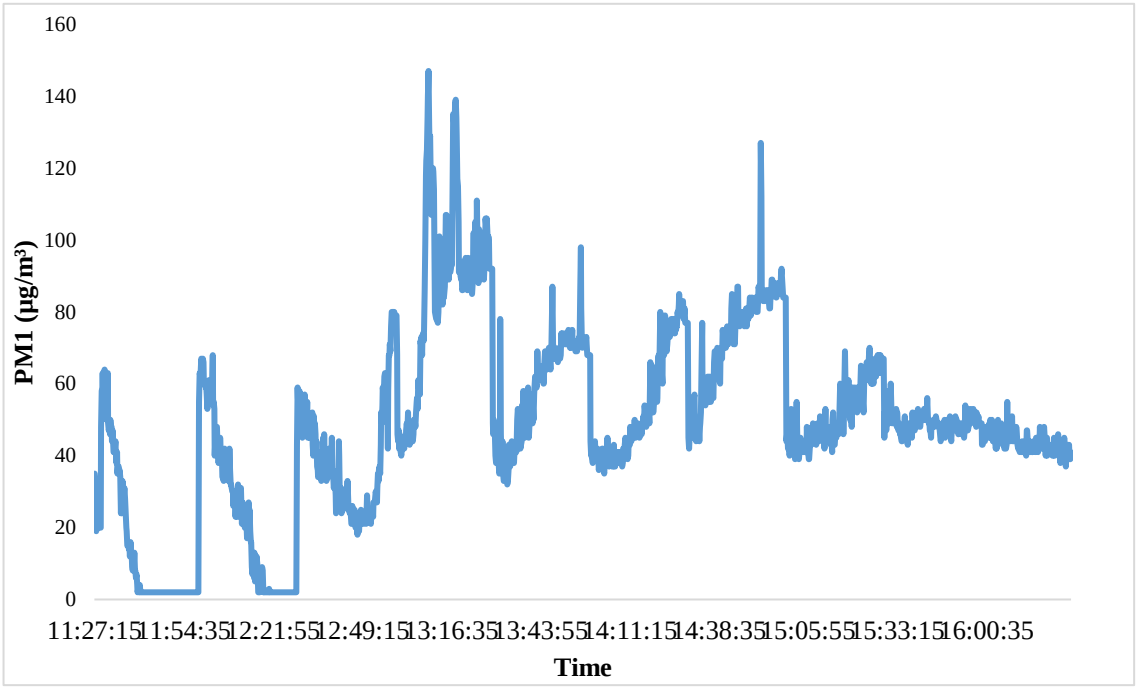


Figure 4.5 $PM_1$ hourly data for DTU monitoring site

$PM_1$ values shows that during the day time its value is on the lower side between 20-60 µg/m³ and as the traffic in the area gets to its peak value and temperature also rises in the afternoon so does the values of $PM_1$ are on the higher side during this event i.e. between 100-150 µg/m³, respectively. Highest value for $PM_1$ was found at 01:00 pm in the

afternoon which could be due to low wind velocity, high temperature and at this hour the session break (lunch time) starts in the university, thereby vehicles movement also tends to increase during this time between 01:00 – 02:00 pm in the afternoon, so there is an uplift of values.

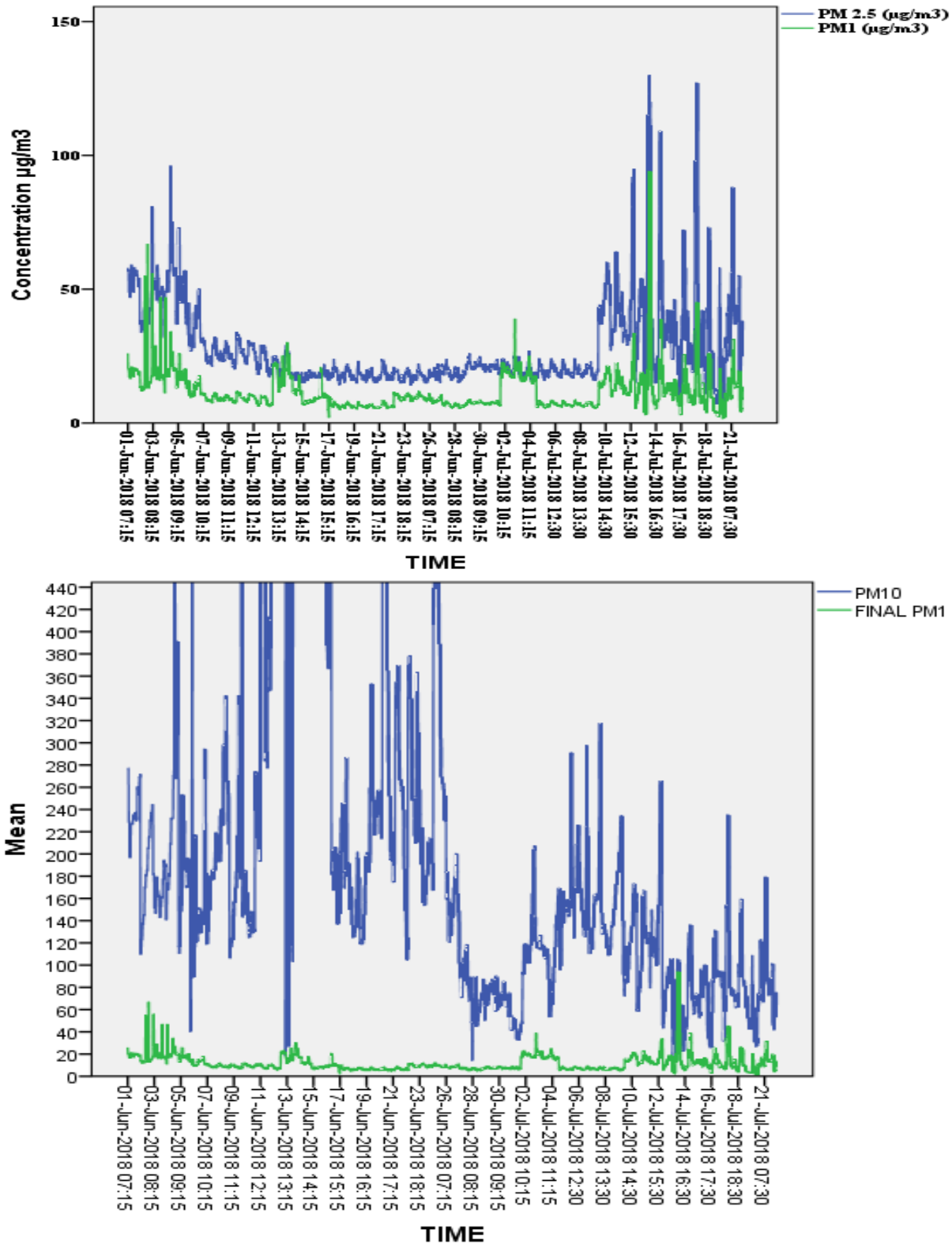


Figure 4.6 $PM_1$ comparison with $PM_{2.5}$ and $PM_{10}$

The following figures above display the $PM_1$ comparison with $PM_{2.5}$ and $PM_{10}$ for the recorded session at the monitoring location. As it was clearly seen that the values of $PM_{10}$ were far greater than the $PM_{2.5}$ or $PM_1$ concentrations. This was mostly due to heavy dust storms arising into Delhi city in the month of June, as the wind-direction changed from North-West to South-West as per the reports of many journals and newspapers. The report given by Times of India news reporter quoted that "The high pollution levels seen at this time of the year in Delhi were unusual and primarily due to dust storms from Rajasthan". The air quality plunged into the 'severe' category due to the dusty conditions which trapped the city under a blanket of heat and particulate matter. $PM_{10}$ levels shoot up to all time high levels specifically rose upto eight times over the standard levels (100 $\mu g/m^3$).

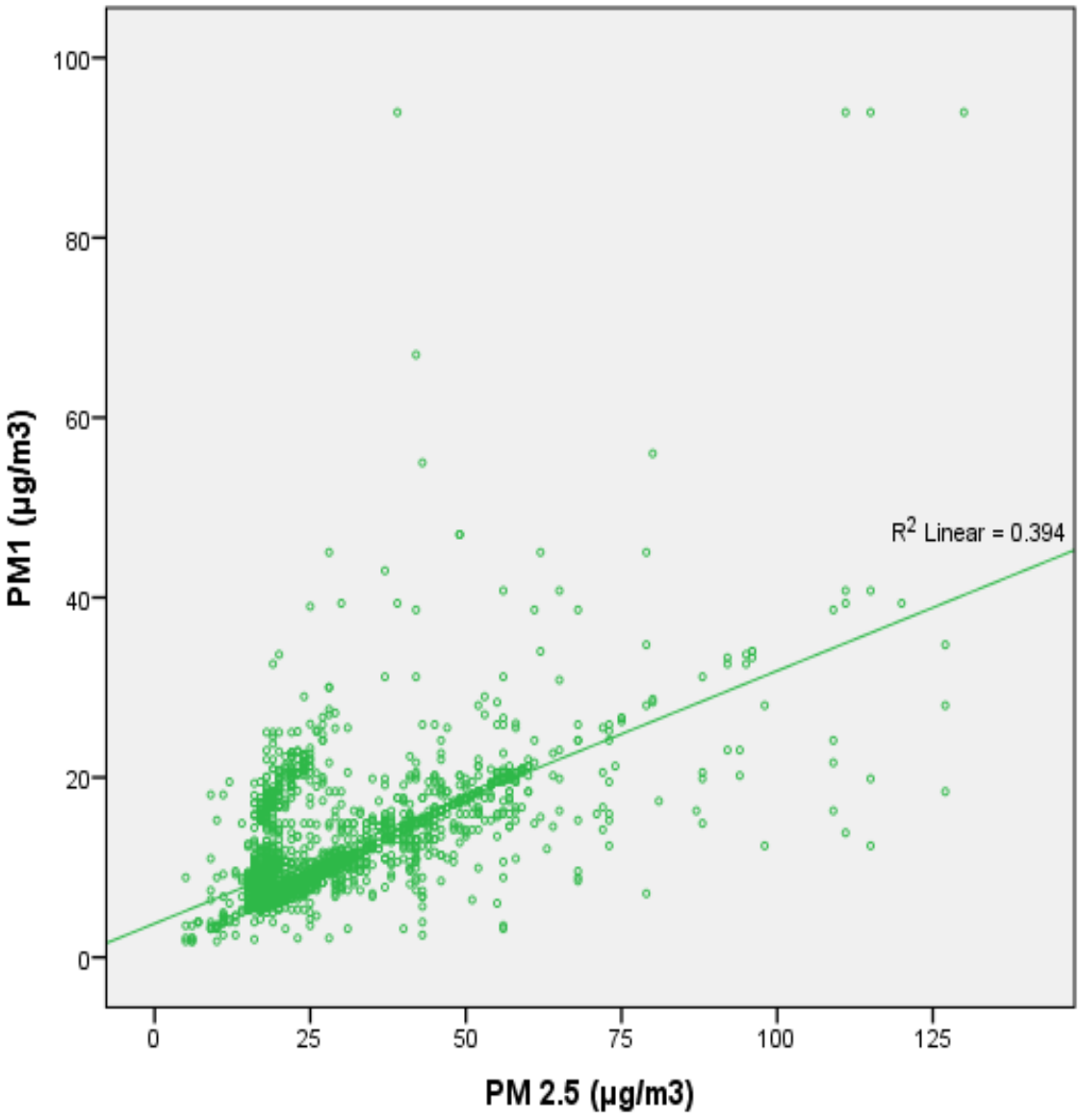


Figure 4.7 Relationship between $PM_1$ and $PM_{2.5}$ using Linear Regression

The graph above in the Figure 4.7 shows the Regression ($R^2$) relationship of $PM_1$ with $PM_{2.5}$ concentrations at the monitoring site with the duration of 50 days. This $R^2$ value is comparatively low as compared to other research work done by for example: Shiva Nagendra *et al* 2010. In this dissertation, the $R^2$ value is found as 0.394, which does not shows a strong relationship between these two pollutants, but as we already know there is a strong relation b/w the two PM concentrations. This might be due to less monitoring time duration considered and may be due to the drizzling effect in the pre-monsoon period. So, it is recommended to increase the time duration for minimum 6 months to 1 year for better results.

### 4.4 Relationship of Particulate Matter with Precursor Gases

The ambient air pollutants $PM_{2.5}$, $NO_x$, CO and $O_3$ concentration values are shown in Figure 4.8. It explains the flow patterns of pollutants during the summer and pre-monsoon season at the study area. The maximum values observed for $PM_{2.5}$, $NO_x$, CO and $O_3$ concentration were 265 µg/m³, 44.3 (ppb), 2620 and 187.9 µg/m³, respectively. The temporal variations of pollutant are strongly influenced by traffic density at monitoring site. The atmospheric conditions are highly turbulent because of wind speed and frequent change in wind directions.

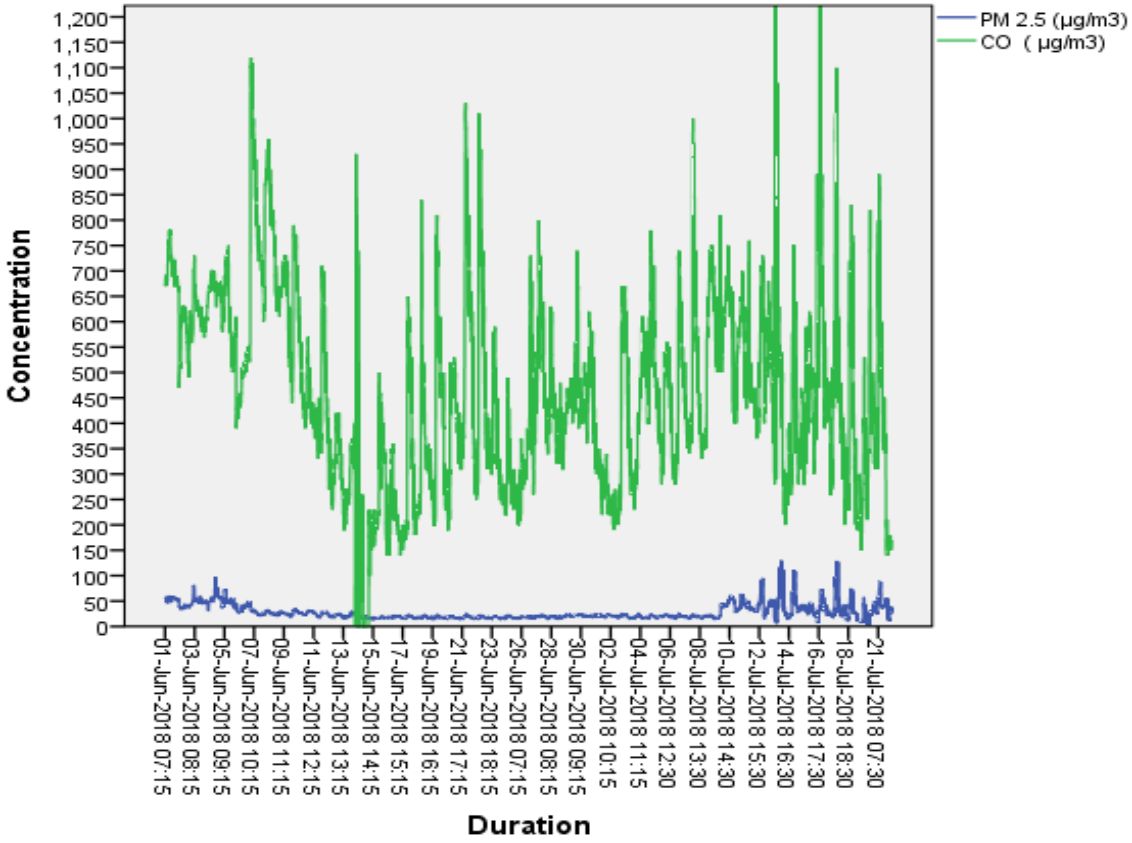


Figure 4.8 (a) Relationship between $PM_{2.5}$ and CO at the monitoring location

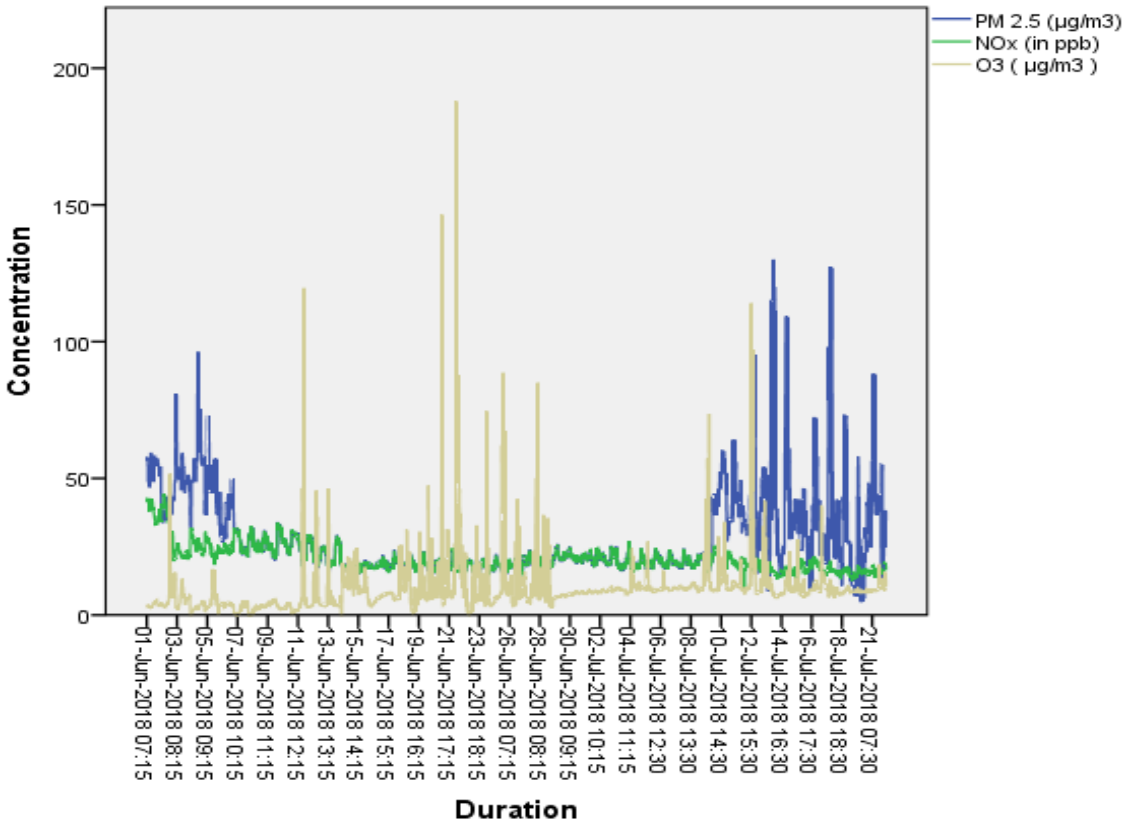


Figure 4.8 (b) Relationship between $PM_{2.5}$ and $NO_x$, $O_3$ at the monitoring location

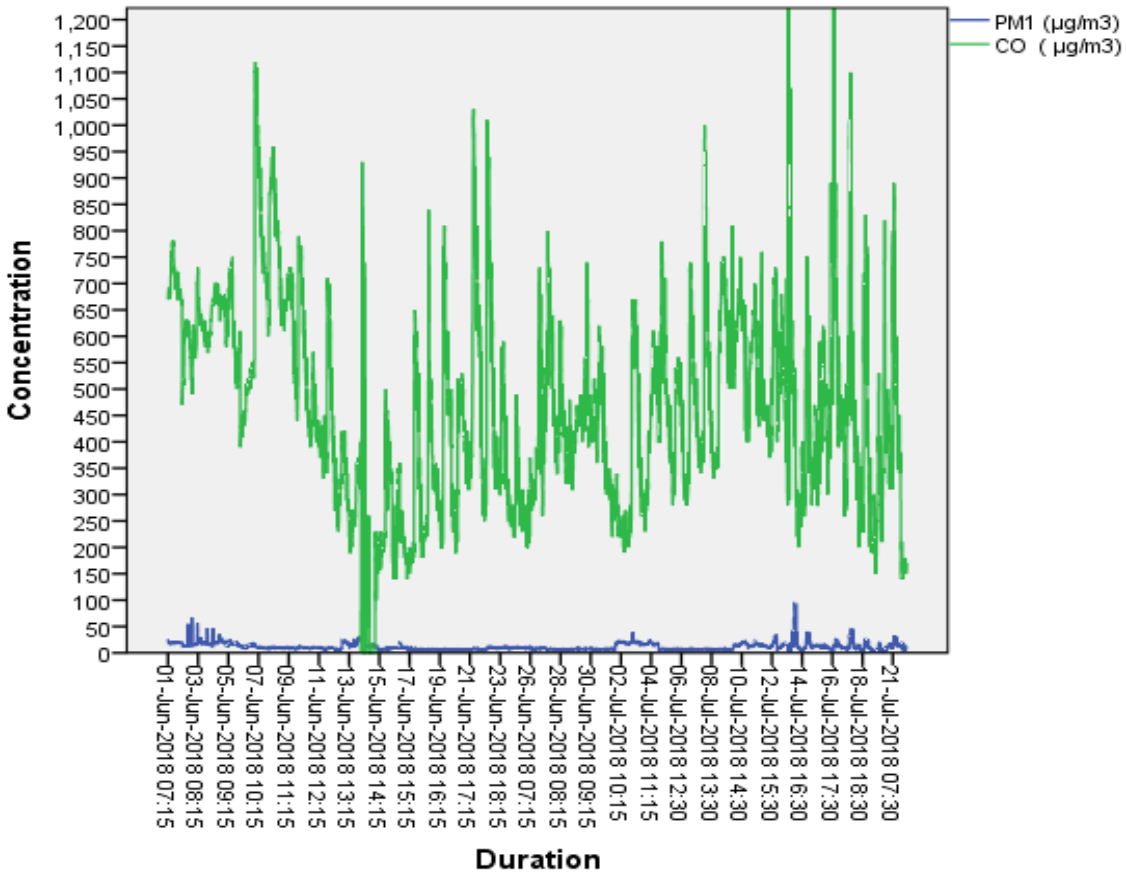


Figure 4.9 (a) Relationship between $PM_1$ and CO at the monitoring location

The graphs presented in figure 4.9 (a) and 4.9 (b) shows the comparison between $PM_1$ and the precursor gases ($NO_X$, CO and $O_3$), respectively. The concentration of CO were typically higher value was observed on 13th of July at evening time, it could be due to the inversion conditions, trapping of pollutant and poor dispersion conditions and suspensions of particulate matter $PM_1$ at the monitoring site. At this time, the university timings were over and all the students and staff members of the university leave for their homes that's the reason the concentrations of ambient air pollutants were higher due to movement of vehicles at DTU gate.

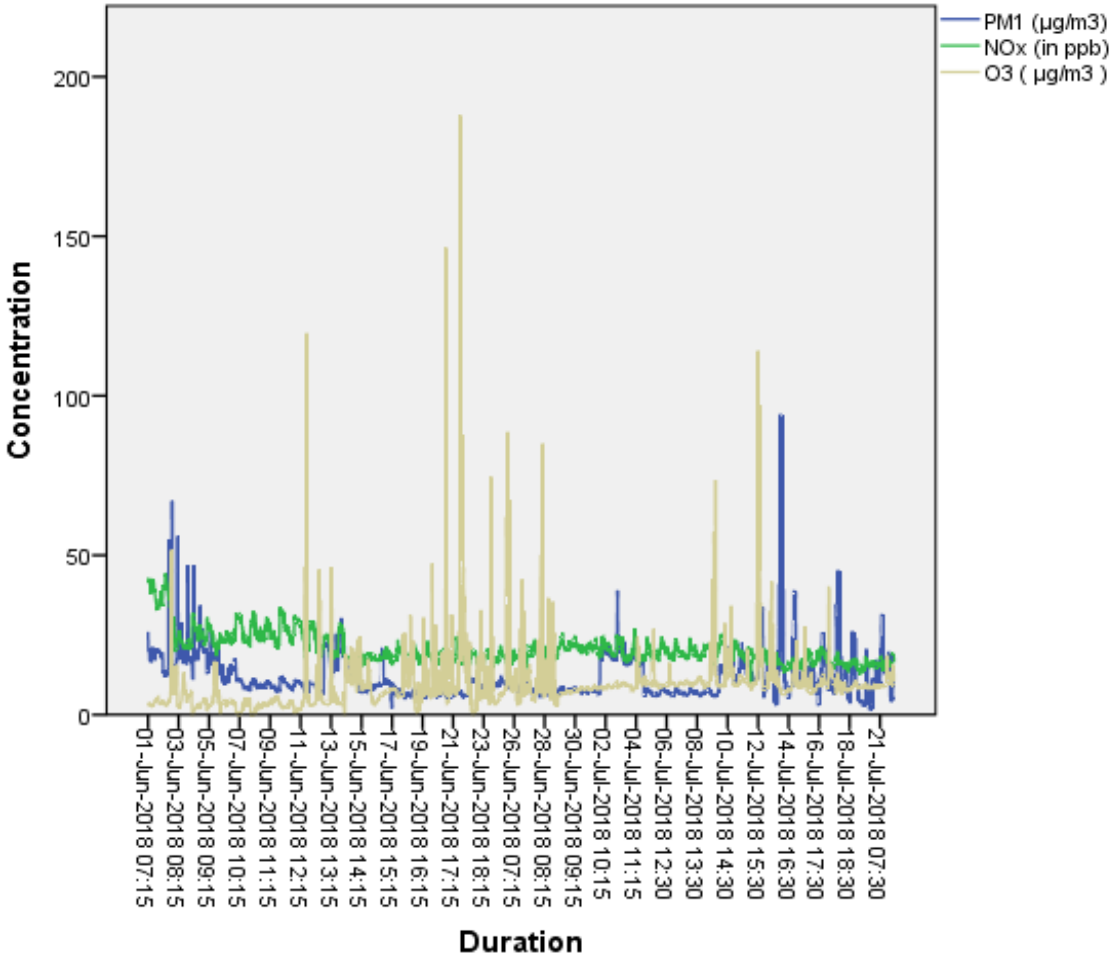


Figure 4.9 (b) Relationship between $PM_1$ and $NO_x$, $O_3$ at the monitoring location

### 4.5 Relationship of Particulate Matter with Meteorological Data

Figure 4.10 represents the distribution of concentration values of $PM_{2.5}$ with relative humidity (RH) and temperature (AT). The concentrations of $PM_{2.5}$ (265 µg/m³) were highest on 14th of July in the morning session, whereas the lowest value of 5 µg/m³ was observed on 20th July in the afternoon time at the monitoring site. The higher values were observed due to hot summers and high temperatures and lower values were recorded due to slight rainfall during the pre-monsoon period. Also it may be due to high moisture content in the atmosphere which definitely changes the flow patterns and therefore change the overall concentrations (Biglari, H., *et al.* 2017).

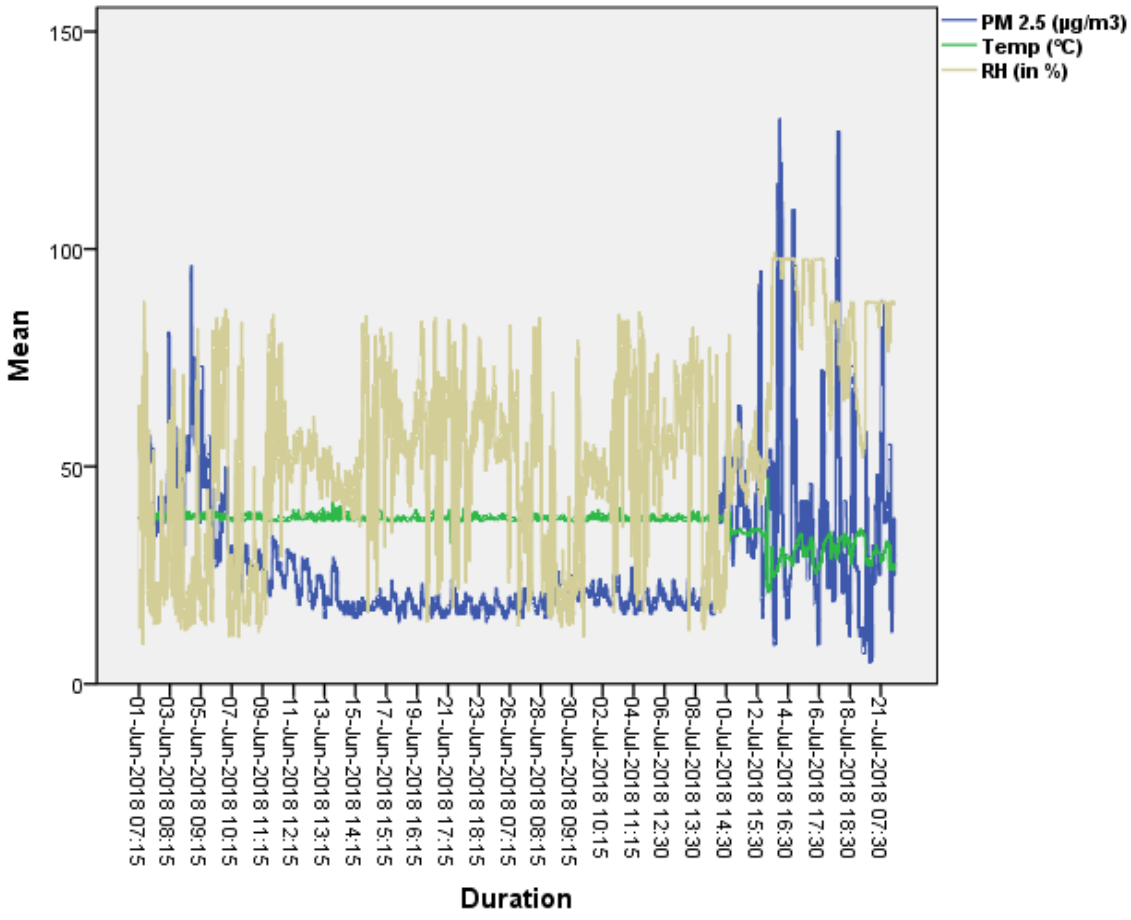


Figure 4.10 Relationship between $PM_{2.5}$ and RH & Temperature at the monitoring site

Similarly, $PM_1$ concentrations were also recorded during the same time and same location as $PM_{2.5}$ as shown in figure 4.11. The highest concentrations for $PM_1$ were observed on same day of summer during the morning time due to low mixing height and low wind speeds blowing, whereas the lowest concentrations were found on 4th of July between 04:00 – 05:00 pm in the late afternoon session at the sampling site.

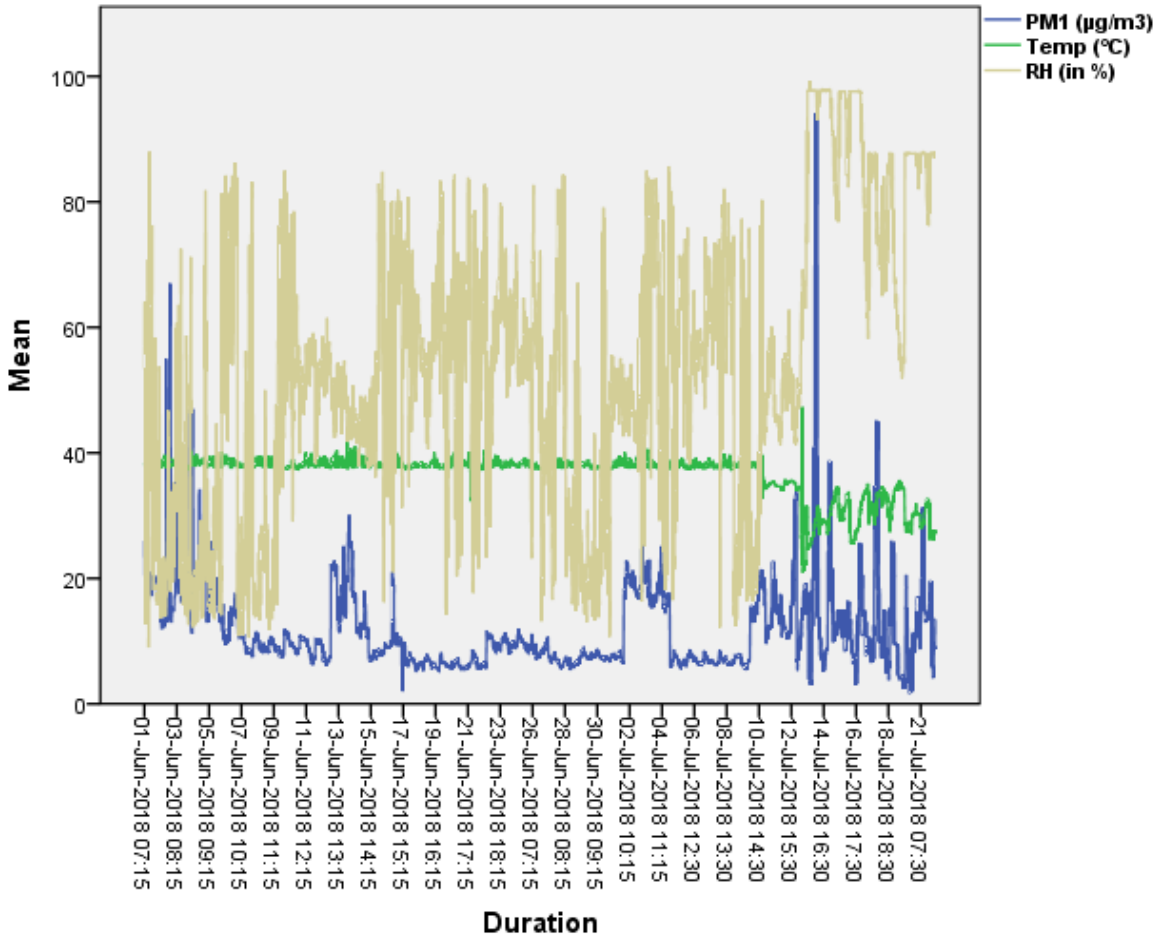


Figure 4.11 Relationship between $PM_1$ and RH & Temperature at the monitoring site

### 4.6 Particulate Matter vs Precursor Gases and Meteorological Data

Finally with the help of statistical tool SPSS we have established the relationship between PM concentrations with Precursor Gases ($NO_x$, CO, $O_3$) and Meteorological Data (RH and AT) for $PM_1$ with all parameters and $PM_{2.5}$ with all parameters, respectively. In this multiple-regression test, we have low to medium $R^2$ value between the variables as shown in Table 5. The maximum closest regression relationship for $PM_1$ concentrations comes with $PM_{2.5}$, therefore it shows the closest relationship with $PM_{2.5}$ and then followed by its relationship with precursor gases in the descending order such that ($NO_x$ < CO < $O_3$) and the least relation comes with the meteorological factors (AT < RH), respectively. In the case of $PM_{2.5}$, somewhat different trend was observed here, as it showed a higher regression value with CO followed by $NO_x$ and then $O_3$ such that (CO < $NO_x$ < $O_3$), respectively. The values for regression have been shown below in the Figures 4.12 and 4.13.

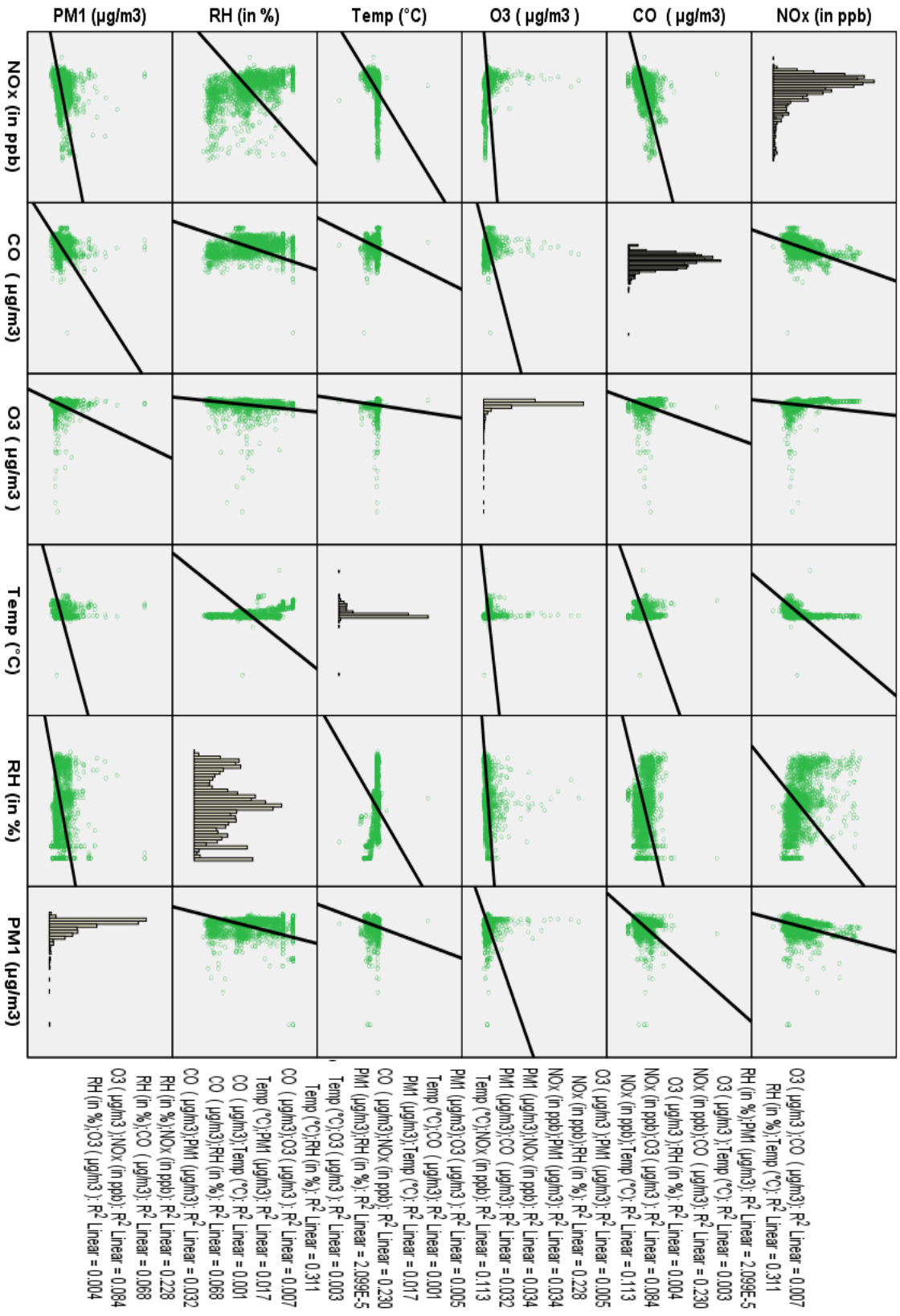


Figure 4.12 Relationship between $PM_1$ with $NO_X$, CO, $O_3$, AT and RH using Linear Regression

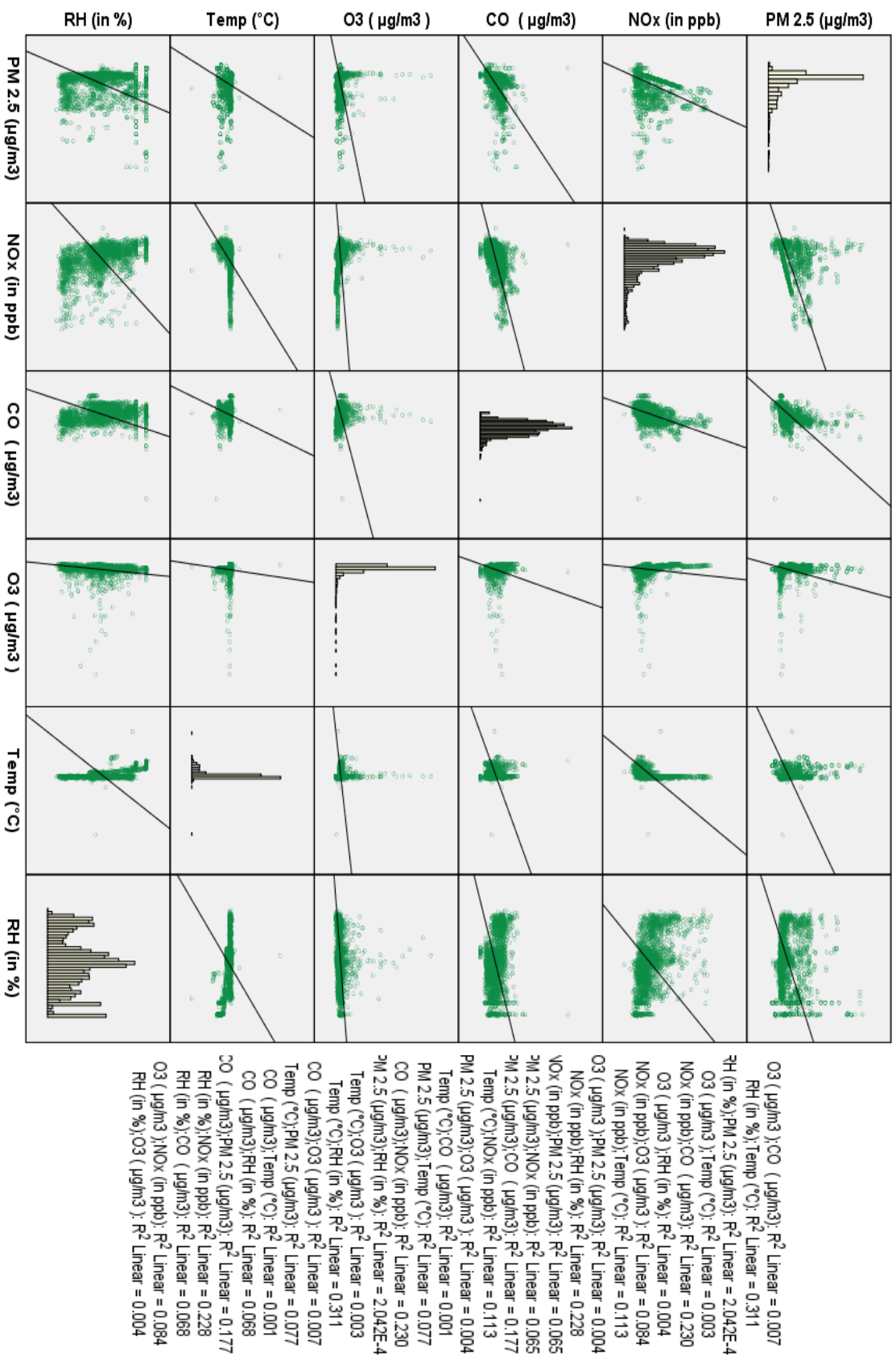


Figure 4.13 Relationship between $PM_{2.5}$ with $NO_X$, CO, $O_3$, AT and RH using Linear Regression

The table given below shows the regression values for relationship between $PM_1$ with $PM_{2.5}$, $NO_x$, CO, $O_3$, AT, RH and for $PM_{2.5}$ with $NO_x$, CO, $O_3$, AT, RH during the duration taken into consideration.

Table 5. Regression values of Variables

| Description | Season | $R^2$ Value | Time Period |
|---|---|---|---|
| $PM_1$ vs $PM_{2.5}$ | Summer and Pre-Monsoon | 0.394 | Day |
| $PM_1$ vs $NO_x$ | Summer and Pre-Monsoon | 0.034 | Day |
| $PM_1$ vs $O_3$ | Summer and Pre-Monsoon | 0.005 | Day |
| $PM_1$ vs CO | Summer and Pre-Monsoon | 0.025 | Day |
| $PM_1$ vs AT | Summer and Pre-Monsoon | 0.017 | Day |
| $PM_1$ vs RH | Summer and Pre-Monsoon | $2.099e^{-5}$ | Day |
| $PM_{2.5}$ vs $NO_x$ | Summer and Pre-Monsoon | 0.065 | Day |
| $PM_{2.5}$ vs $O_3$ | Summer and Pre-Monsoon | 0.004 | Day |
| $PM_{2.5}$ vs CO | Summer and Pre-Monsoon | 0.171 | Day |
| $PM_{2.5}$ vs AT | Summer and Pre-Monsoon | 0.077 | Day |
| $PM_{2.5}$ vs RH | Summer and Pre-Monsoon | $2.042e^{-4}$ | Day |

Note: AT symbolises Ambient Temperature, RH represents Relative Humidity

The regression value of superfine particles ($PM_1$) with fine particles ($PM_{2.5}$) is less than 0.5 and does not shows a strong relationship between these two pollutant concentrations but as we could understand from previous works that $PM_1$ and $PM_{2.5}$ concentrations has a close relationship. This may be due to less time duration taken (i.e. 50 days), respectively. Since, we got very low regression values for $PM_1$ with all the variables which justifies the less duration of time selected for the monitoring data or other factors responsible for this may be high temperature and high relative humidity during summer and pre-monsoon season.

# CHAPTER – 5

## CONCLUSION and RECOMMENDATIONS

### 5.1 Conclusion

As $PM_{2.5}$ and $PM_{10}$ are the notorious pollutants but $PM_1$ is also playing a vital role in particulate matter emissions. DTU, Delhi is getting more vehicular emissions exposure comparative to other sources. This study evaluates the relationship of $PM_1$ and $PM_{2.5}$ with their affecting factors (Precursor Gases & Meteorological Data) but the concentration of the Particulate matter for the duration were quite low as compared to other event days, due to this, it could not able to establish a strong relationship. Though higher mixing height and higher wind speed has helped in better dispersion of $PM_1$ and $PM_{2.5}$. However, few episodes of dust storms have also elevated the $PM_{10}$ level during the month. Every year (as studied 2016 - 2018) the month June experiences at least two spikes in particulate concentrations ($1^{st}$ - $5^{th}$ June) and ($10^{th}$ to $16^{th}$ June). This may be attributed to the changing weather condition like increase in temperature, development of low pressure zone over Delhi, which finally allow the air intrusion from West and South-West direction carrying dry dust resulting into high particulate matter and hazy condition over Delhi. This thesis work concludes that for establishing the relationship of fine and superfine particulate matters with their affecting factors (precursor gases and meteorological data) it is needed to consider the long-time data monitoring duration along with different seasons.

### 5.2 Recommendations

It is highly recommended that data should be collected for a longer period upto 6 months or more and in different seasons also for a better relationship of fine and superfine particulate matter with precursor gases and meteorological factors. So as to develop a model and computational simulation analysis to present and validate secondary data with the primary monitored data which can provide reasonable accuracy to predict the air pollution exposure at any site.

# ANNEXURE I – NAAQS

| Sr. No. | Pollutant | Time Weighted Average | Concentration in Ambient Air | | Methods of Measurement |
|---|---|---|---|---|---|
| | | | Industrial, Residential, Rural and Other Areas | Ecologically Sensitive Area | |
| 1. | Sulphur Dioxide ($SO_2$), $\mu g/m^3$ | Annual* | 50 | 20 | **1. Improved West and Gaeke 2. Ultraviolet Fluorescence** |
| | | 24 hours** | 80 | 80 | |
| 2. | Nitrogen Dioxide ($NO_2$), $\mu g/m^3$ | Annual* | 40 | 30 | **1. Modified Jacob & Hochheiser (Na-Arsenite) 2. Chemiluminescence** |
| | | 24 hours** | 80 | 80 | |
| 3. | Particulate Matter (size less than 10 µm) or $PM_{10}$ $\mu g/m^3$ | Annual* | 60 | 60 | **1. Gravimetric 2. TOEM 3. Beta attenuation** |
| | | 24 hours** | 100 | 100 | |
| 4. | Particulate Matter (size less than 2.5 µm) or $PM_{2.5}$ $\mu g/m^3$ | Annual* | 40 | 40 | **1. Gravimetric 2. TOEM 3. Beta attenuation** |
| | | 24 hours** | 60 | 60 | |
| 5. | Ozone ($O_3$) $\mu g/m^3$ | 8 hours* | 100 | 100 | **1. UV photometric 2. Chemiluminescence 3. Chemical Method** |
| | | 1 hour* | 180 | 180 | |
| 6. | Lead (Pb) $\mu g/m^3$ | Annual* | 0.50 | 0.50 | **1. AAS/ICP Method after sampling using EPM 2000 or equivalent filter paper 2. ED-XRF using Teflon filter** |
| | | 24 hours** | 1.0 | 1.0 | |
| 7. | Carbon Monoxide (CO) $mg/m^3$ | 8 hours* | 02 | 02 | **Non dispersive Infra-Red (NDIR) Spectroscopy** |
| | | 1 hour* | 04 | 04 | |
| 8. | Ammonia ($NH_3$) $\mu g/m^3$ | Annual* | 100 | 100 | **1. Chemiluminescence 2. Indophernol blue method** |
| | | 24 hours** | 400 | 400 | |
| 9. | Benzene ($C_6H_6$) $\mu g/m^3$ | Annual* | 05 | 05 | **1. Gas chromatography based continuous analyzer 2. Adsorption and Desorption followed by GC analysis** |
| 10. | Benzo(a)Pyrene (BaP)-particulate phase only $ng/m^3$ | Annual* | 01 | 01 | **Solvent extraction followed by HPLC/GC analysis** |
| 11. | Arsenic(As) $ng/m^3$ | Annual* | 06 | 06 | **AAS/ICP method after sampling on EPM 2000 or equivalent filter paper** |
| 12. | Nickel (Ni) $ng/m^3$ | Annual* | 20 | 20 | **AAS/ICP method after sampling on EPM 2000 or equivalent filter paper** |

**Annual Arithmetic mean of minimum 104 measurements in a year at a particular site taken twice a week 24 hourly at uniform interval.*

*** 24 hourly 08 hourly or 01 hourly monitored values, as applicable shall be complied with 98% of the time in a year. 2% of the time, they may exceed the limits but not on two consecutive days of monitoring.*

ANNEXURE II – METEOROLOGICAL DATA

## Daily Meteorological Data - June 2018

| Meteorological Parameters | 01-02 Jun | 02-03 Jun | 03-04 Jun | 04-05 Jun | 05-06 Jun | 06-07 Jun | 07-08 Jun | 08-09 Jun | 09-10 Jun | 10-11 Jun |
|---|---|---|---|---|---|---|---|---|---|---|
| Mixing Height (m) | 914 | 863 | 816 | 770 | 743 | 692 | 808 | 847 | 804 | 594 |
| Wind Speed (m/s) | 4.1 | 3.6 | 3.4 | 4.2 | 4.1 | 3.2 | 2.6 | 4.2 | 3.1 | 1.9 |
| Temperature ($^{O}$C) | 32.0 | 31.1 | 33.0 | 35.0 | 35.0 | 31.2 | 35.2 | 33.9 | 30.2 | 33.6 |
| Relative Humidity(% ) | 50.0 | 51.6 | 53.2 | 49.1 | 50.1 | 62.1 | 50.7 | 57.9 | 70.1 | 55.7 |
| Wind Direction | SE | E | SE | E | E | NE,E | SE,E | E,SE | SE,E | NW,N,W |

| Meteorological Parameters | 11-12 Jun | 12-13 Jun | 13-14 Jun | 14-15 Jun | 15-16 Jun | 16-17 Jun | 17-18 Jun | 18-19 Jun | 19-20 Jun | 20-21 Jun |
|---|---|---|---|---|---|---|---|---|---|---|
| Mixing Height (m) | 651 | 592 | 599 | 694 | 659 | 833 | 942 | 660 | 816 | 556 |
| Wind Speed (m/s) | 3.3 | 3.2 | 4.5 | 4.2 | 3.6 | 3.1 | 2.9 | 3.1 | 2.2 | 2.3 |
| Temperature ($^{O}$C) | 35.9 | 37.9 | 37.9 | 36.9 | 35.2 | 33.7 | 30.6 | 32.0 | 34.2 | 35.7 |
| Relative Humidity(% ) | 45.0 | 41.5 | 36.1 | 36.4 | 41.2 | 51.1 | 56.8 | 51.4 | 46.9 | 44.2 |
| Wind Direction | NW,W | W | W | w | W,SW | Varies | NE | NW | NW,NE | NE |

| Meteorological Parameters | 21-22 Jun | 22-23 Jun | 23-24 Jun | 24-25 Jun | 25-26 Jun | 26-27 Jun | 27-28 Jun | 28-29 Jun | 29-30 Jun | 30 Jun-01 July | Average |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Mixing Height (m) | 600 | 661 | * | * | 527 | 398 | 555 | 801 | 688 | 720 | **785** |
| Wind Speed (m/s) | 2.0 | 1.7 | 2.7 | 2.5 | 3.5 | 2.5 | 3.3 | 4.3 | 3.5 | 2.2 | **3.4** |
| Temperature ($^{O}$C) | 36.5 | 37.7 | 37.1 | 37.1 | 36.1 | 32.1 | 29.3 | 30.2 | 30.2 | 30.8 | **33.0** |
| Relative Humidity(% ) | 41.8 | 39.6 | 38.5 | 38.0 | 42.3 | 54.3 | 76.6 | 71.8 | 69.6 | 31.9 | **55.1** |
| Wind Direction | N,NE | NE,E,SE | NW,N | NW | NW, SW | E,NW | E | E | E,SE | S,SW,SE | **Varies** |

*Inadequate data/Data not available

# ANNEXURE III –LOCATION IMAGES



Particulate Air Monitoring


Ozone Monitor


Model 405 nm
NO2/NO/NOx Monitor
2B Technologies


HORIBA

# ANNEXURE IV – DATA TABLES

| DATE | PM1 (µg/m³) | PM2.5 (µg/m³) | PM10 (µg/m³) | NOx (ppb) | CO (µg/m³) | Ozone (µg/m³) | AT (°C) | RH (%) |
|---|---|---|---|---|---|---|---|---|
| 01-06-2018 07:15 | 48.4 | 58 | 277 | 43 | 670 | 3.3 | 38 | 64 |
| 01-06-2018 07:30 | 43.02 | 57 | 277 | 42.1 | 680 | 3.3 | 38.4 | 53.4 |
| 01-06-2018 07:45 | 46.32 | 57 | 277 | 41.6 | 690 | 3.4 | 38.2 | 64 |
| 01-06-2018 08:00 | 35.25 | 57 | 276 | 41.3 | 690 | 3.1 | 37.8 | 12.7 |
| 01-06-2018 08:15 | 31.6 | 49 | 229 | 41.6 | 670 | 3.2 | 38.2 | 56.5 |
| 01-06-2018 08:30 | 31.69 | 49 | 229 | 41.8 | 680 | 3.2 | 39.9 | 18 |
| 01-06-2018 08:45 | 32.45 | 49 | 229 | 41.9 | 690 | 3.3 | 38 | 52.1 |
| 01-06-2018 09:00 | 36.68 | 49 | 228 | 40.2 | 690 | 3.4 | 38.2 | 35.3 |
| 01-06-2018 09:15 | 26.07 | 47 | 197 | 37.8 | 680 | 3.3 | 39.1 | 46.8 |
| 01-06-2018 09:30 | 26.51 | 47 | 197 | 40.5 | 700 | 3.3 | 38.5 | 27.3 |
| 01-06-2018 09:45 | 27.4 | 47 | 197 | 39.3 | 730 | 3.3 | 38 | 21.5 |
| 01-06-2018 10:00 | 37.83 | 47 | 198 | 38.8 | 760 | 3.2 | 37.7 | 70.8 |
| 01-06-2018 10:15 | 49.04 | 59 | 227 | 40.3 | 750 | 2.8 | 38.9 | 60.6 |
| 01-06-2018 10:30 | 49.82 | 59 | 227 | 41.5 | 760 | 2.9 | 38.4 | 9 |
| 01-06-2018 10:45 | 31.69 | 59 | 227 | 42 | 770 | 2.9 | 37.6 | 34 |
| 01-06-2018 11:00 | 18.32 | 59 | 227 | 41.9 | 780 | 2.9 | 39 | 61.7 |
| 01-06-2018 11:15 | 23.68 | 56 | 227 | 42.3 | 770 | 3.2 | 39 | 88 |
| 01-06-2018 11:30 | 36.32 | 56 | 227 | 42.6 | 780 | 2.9 | 38.6 | 78 |
| 01-06-2018 11:45 | 33.73 | 56 | 227 | 41.9 | 780 | 2.9 | 37.6 | 34 |
| 01-06-2018 12:00 | 27.28 | 56 | 227 | 41.1 | 750 | 3.2 | 38.2 | 54.8 |
| 01-06-2018 12:15 | 20.1 | 50 | 235 | 38.4 | 730 | 3.5 | 38.5 | 63.5 |
| 01-06-2018 12:30 | 28.9 | 49 | 235 | 39.3 | 720 | 3.9 | 38.4 | 43.7 |
| 01-06-2018 12:45 | 22.57 | 49 | 235 | 37.9 | 730 | 4.2 | 39.7 | 67 |
| 01-06-2018 13:00 | 46.99 | 49 | 235 | 37.5 | 720 | 4.2 | 37.9 | 48.5 |
| 01-06-2018 13:15 | 8.45 | 57 | 232 | 36.6 | 690 | 4.4 | 38.3 | 76.3 |
| 01-06-2018 13:30 | 32.95 | 58 | 232 | 35.8 | 710 | 4.7 | 38.4 | 26.7 |
| 01-06-2018 13:45 | 23.31 | 58 | 232 | 35.2 | 720 | 5 | 37.8 | 25.6 |
| 01-06-2018 14:00 | 49.76 | 58 | 232 | 34.9 | 720 | 4.7 | 37.9 | 20.7 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 01-06-2018 14:15 | 46.08 | 55 | 237 | 33.4 | 690 | 4.8 | 37.9 | 21.7 |
| 01-06-2018 14:30 | 41.31 | 55 | 237 | 33.5 | 690 | 5 | 38.1 | 18.1 |
| 01-06-2018 14:45 | 56.92 | 55 | 237 | 33.5 | 710 | 5.4 | 37.8 | 26.5 |
| 01-06-2018 15:00 | 32.06 | 55 | 236 | 33.2 | 710 | 5.1 | 37.8 | 29.1 |
| 01-06-2018 15:15 | 52.78 | 56 | 230 | 33.2 | 670 | 5.4 | 39.2 | 56.6 |
| 01-06-2018 15:30 | 64.43 | 57 | 230 | 32.9 | 670 | 5.5 | 37.7 | 58.4 |
| 01-06-2018 15:45 | 44.41 | 57 | 230 | 33.9 | 720 | 4.4 | 38.4 | 31.8 |
| 01-06-2018 16:00 | 42.01 | 57 | 231 | 33.9 | 720 | 3.8 | 38.3 | 30.1 |
| 01-06-2018 16:15 | 57.4 | 55 | 260 | 34.2 | 680 | 3.5 | 39 | 16.4 |
| 01-06-2018 16:30 | 57.37 | 55 | 260 | 35 | 690 | 3.4 | 38 | 27.7 |
| 01-06-2018 16:45 | 54.24 | 55 | 260 | 36.4 | 680 | 3.4 | 38.6 | 19.6 |
| 01-06-2018 17:00 | 46.56 | 55 | 260 | 35.6 | 690 | 3.4 | 38.1 | 17 |
| 01-06-2018 17:15 | 43.98 | 51 | 254 | 36.8 | 670 | 3.3 | 38.5 | 22.7 |
| 01-06-2018 17:30 | 42.56 | 51 | 254 | 38.8 | 680 | 3.3 | 38.5 | 15.7 |
| 01-06-2018 17:45 | 38.5 | 51 | 254 | 36.8 | 680 | 3.5 | 38.7 | 19.5 |
| 01-06-2018 18:00 | 41.45 | 51 | 255 | 35.3 | 680 | 3.7 | 38 | 25.9 |
| 01-06-2018 18:15 | 33.4 | 54 | 269 | 35.5 | 670 | 3.8 | 38.3 | 41.9 |
| 01-06-2018 18:30 | 34.83 | 54 | 269 | 34.3 | 660 | 4.1 | 39.4 | 29 |
| 01-06-2018 18:45 | 34.92 | 54 | 269 | 34.8 | 670 | 4.3 | 38.7 | 53.8 |
| 01-06-2018 19:00 | 35.76 | 54 | 272 | 34.1 | 660 | 4.7 | 37.9 | 52.7 |
| 02-06-2018 07:15 | 27.7 | 37 | 110 | 39.2 | 470 | 3.6 | 37.8 | 19.2 |
| 02-06-2018 07:30 | 21.08 | 38 | 110 | 40.1 | 490 | 3.5 | 37.9 | 18.1 |
| 02-06-2018 07:45 | 21.43 | 38 | 110 | 40.7 | 510 | 3.7 | 37.9 | 13.6 |
| 02-06-2018 08:00 | 22.15 | 38 | 111 | 40.3 | 520 | 3.6 | 38.2 | 16.5 |
| 02-06-2018 08:15 | 27.37 | 34 | 123 | 40.7 | 510 | 3.7 | 37.9 | 20.9 |
| 02-06-2018 08:30 | 28.26 | 34 | 123 | 39.9 | 530 | 3.8 | 38.3 | 18.4 |
| 02-06-2018 08:45 | 28.71 | 34 | 123 | 39.1 | 560 | 3.7 | 37.6 | 22.5 |
| 02-06-2018 09:00 | 18.26 | 34 | 124 | 40.8 | 600 | 3.4 | 38.9 | 23.2 |
| 02-06-2018 09:15 | 11.18 | 36 | 137 | 43 | 590 | 3.1 | 38.8 | 18.1 |
| 02-06-2018 09:30 | 16.07 | 38 | 137 | 44.3 | 610 | 3 | 38.9 | 13.9 |
| 02-06-2018 09:45 | 24.64 | 38 | 137 | 43.5 | 620 | 3 | 38.8 | 19.3 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 02-06-2018 10:00 | 22.89 | 38 | 137 | 43.8 | 630 | 3 | 38.2 | 16.2 |
| 02-06-2018 10:15 | 17.53 | 36 | 145 | 43 | 620 | 3 | 37.9 | 23.4 |
| 02-06-2018 10:30 | 14.07 | 35 | 145 | 41.7 | 630 | 2.9 | 39 | 14 |
| 02-06-2018 10:45 | 20.64 | 35 | 145 | 41.2 | 630 | 3.2 | 38.7 | 16.4 |
| 02-06-2018 11:00 | 13.73 | 35 | 145 | 40.8 | 630 | 3.5 | 39.7 | 18.2 |
| 02-06-2018 11:15 | 40.28 | 42 | 170 | 38.9 | 620 | 3.8 | 38.4 | 19.2 |
| 02-06-2018 11:30 | 6.37 | 43 | 170 | 37.6 | 610 | 4 | 38.4 | 22.3 |
| 02-06-2018 11:45 | 24.43 | 43 | 170 | 37.5 | 630 | 3.9 | 38.8 | 14 |
| 02-06-2018 12:00 | 17.28 | 43 | 170 | 36.4 | 620 | 4.2 | 37.5 | 16.8 |
| 02-06-2018 12:15 | 31.74 | 37 | 181 | 36.1 | 600 | 4.2 | 38.4 | 17.2 |
| 02-06-2018 12:30 | 31 | 37 | 181 | 36.5 | 600 | 4.5 | 38.1 | 18 |
| 02-06-2018 12:45 | 27.79 | 37 | 181 | 36.1 | 610 | 4.4 | 38 | 24.1 |
| 02-06-2018 13:00 | 38.29 | 37 | 181 | 34.1 | 610 | 4.7 | 39.2 | 28 |
| 02-06-2018 13:15 | 22.73 | 39 | 185 | 33.7 | 580 | 4.9 | 38.1 | 40.1 |
| 02-06-2018 13:30 | 36.76 | 39 | 185 | 34.6 | 580 | 5.1 | 38.6 | 46.8 |
| 02-06-2018 13:45 | 44.08 | 39 | 185 | 32.3 | 560 | 14.9 | 38.7 | 23.3 |
| 02-06-2018 14:00 | 30.39 | 39 | 186 | 28.3 | 560 | 20.1 | 38.8 | 25.9 |
| 02-06-2018 14:15 | 30.22 | 41 | 205 | 27.7 | 520 | 22 | 38.7 | 42.4 |
| 02-06-2018 14:30 | 43.83 | 42 | 205 | 27.1 | 520 | 51.7 | 38.3 | 23.8 |
| 02-06-2018 14:45 | 43.81 | 42 | 205 | 26.9 | 520 | 24.2 | 38.1 | 20.2 |
| 02-06-2018 15:00 | 41.42 | 42 | 205 | 27.4 | 500 | 9.7 | 38.6 | 28.4 |
| 02-06-2018 15:15 | 32.17 | 38 | 215 | 28.4 | 490 | 6.4 | 38.1 | 25.8 |
| 02-06-2018 15:30 | 31.91 | 37 | 215 | 28.1 | 520 | 9.8 | 37.7 | 17.9 |
| 02-06-2018 15:45 | 30.88 | 37 | 215 | 28.8 | 570 | 6.8 | 38 | 33.9 |
| 02-06-2018 16:00 | 27.93 | 37 | 216 | 28.8 | 620 | 6.5 | 38.7 | 28.1 |
| 02-06-2018 16:15 | 34.13 | 42 | 230 | 30.8 | 620 | 9.6 | 38.3 | 20.8 |
| 02-06-2018 16:30 | 26.6 | 43 | 230 | 29.3 | 610 | 9.4 | 39.1 | 28.7 |
| 02-06-2018 16:45 | 27.73 | 43 | 230 | 29.4 | 610 | 6.6 | 38 | 22 |
| 02-06-2018 17:00 | 27.81 | 43 | 234 | 27.9 | 590 | 6.7 | 38.4 | 20.8 |
| 02-06-2018 17:15 | 27.82 | 42 | 237 | 20.1 | 560 | 6.9 | 38.1 | 26.6 |
| 02-06-2018 17:30 | 31.44 | 42 | 237 | 19.7 | 560 | 12 | 37.9 | 19.4 |

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|---|---|---|---|---|---|---|---|---|
| 02-06-2018 17:45 | 23.3 | 42 | 237 | 20.5 | 560 | 15.2 | 38.4 | 20.2 |
| 02-06-2018 18:00 | 23.69 | 42 | 237 | 20.7 | 560 | 10.8 | 38.4 | 27.4 |
| 02-06-2018 18:15 | 27.98 | 48 | 244 | 19.8 | 560 | 8.3 | 38.1 | 26.2 |
| 02-06-2018 18:30 | 39.44 | 49 | 244 | 20.4 | 570 | 15.6 | 37.9 | 35.3 |
| 02-06-2018 18:45 | 40.73 | 49 | 244 | 20.8 | 580 | 15.1 | 38.3 | 21.9 |
| 02-06-2018 19:00 | 41.37 | 49 | 244 | 20.5 | 590 | 11.5 | 37.9 | 32 |
| 03-06-2018 07:15 | 43.5 | 81 | 182 | 23.6 | 700 | 3 | 37.5 | 44.9 |
| 03-06-2018 07:30 | 24.84 | 80 | 182 | 23.8 | 700 | 3 | 39.7 | 59.9 |
| 03-06-2018 07:45 | 33.82 | 80 | 182 | 23.5 | 710 | 2.8 | 39.2 | 30.7 |
| 03-06-2018 08:00 | 51.88 | 80 | 181 | 24.2 | 730 | 2.4 | 39.5 | 57.6 |
| 03-06-2018 08:15 | 33.13 | 55 | 152 | 24.8 | 690 | 2.2 | 37.9 | 60.7 |
| 03-06-2018 08:30 | 26.3 | 54 | 152 | 24 | 670 | 2.6 | 39.2 | 55.4 |
| 03-06-2018 08:45 | 21.7 | 54 | 152 | 24.2 | 670 | 2.9 | 38.1 | 58.6 |
| 03-06-2018 09:00 | 31.85 | 54 | 152 | 26.5 | 660 | 2.8 | 37.7 | 40.4 |
| 03-06-2018 09:15 | 24.56 | 50 | 147 | 25.7 | 650 | 2.5 | 38.4 | 36.6 |
| 03-06-2018 09:30 | 47.95 | 50 | 147 | 25.5 | 650 | 2.6 | 38 | 40.4 |
| 03-06-2018 09:45 | 7.41 | 50 | 147 | 24.3 | 640 | 3 | 40.2 | 63.6 |
| 03-06-2018 10:00 | 28.41 | 50 | 149 | 23.3 | 630 | 3.8 | 39.2 | 54.3 |
| 03-06-2018 10:15 | 21.3 | 53 | 179 | 23.6 | 620 | 4 | 37.6 | 20 |
| 03-06-2018 10:30 | 45.47 | 53 | 179 | 22.9 | 630 | 4.4 | 37.9 | 26.7 |
| 03-06-2018 10:45 | 44.41 | 53 | 179 | 23.4 | 640 | 5.2 | 39.7 | 30.9 |
| 03-06-2018 11:00 | 39.81 | 53 | 179 | 22 | 640 | 7 | 38.1 | 39.8 |
| 03-06-2018 11:15 | 47.6 | 46 | 167 | 22.4 | 630 | 7.8 | 38 | 46.1 |
| 03-06-2018 11:30 | 26.81 | 46 | 167 | 22.7 | 620 | 8.8 | 38.6 | 72.5 |
| 03-06-2018 11:45 | 43.36 | 46 | 167 | 21.3 | 630 | 10.4 | 37.9 | 27 |
| 03-06-2018 12:00 | 51.99 | 46 | 166 | 21.1 | 620 | 10.9 | 37.8 | 22.4 |
| 03-06-2018 12:15 | 45.19 | 58 | 162 | 22.2 | 610 | 11.3 | 37.6 | 17.3 |
| 03-06-2018 12:30 | 43.49 | 59 | 162 | 21.1 | 620 | 12.3 | 38.2 | 21 |
| 03-06-2018 12:45 | 61.58 | 59 | 162 | 20.6 | 610 | 13.3 | 37.6 | 22.6 |
| 03-06-2018 13:00 | 61.54 | 59 | 161 | 21.4 | 610 | 10.4 | 37.9 | 15.8 |
| 03-06-2018 13:15 | 53.26 | 54 | 143 | 20.7 | 590 | 10.2 | 38.8 | 18.9 |

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|---|---|---|---|---|---|---|---|---|
| 03-06-2018 13:30 | 45.72 | 54 | 143 | 20.9 | 610 | 9.3 | 37.8 | 18.6 |
| 03-06-2018 13:45 | 46.57 | 54 | 143 | 21.6 | 630 | 6.3 | 38.2 | 23.6 |
| 03-06-2018 14:00 | 45.06 | 54 | 143 | 21.1 | 620 | 7.7 | 37.7 | 41.7 |
| 03-06-2018 14:15 | 34.72 | 46 | 153 | 20.7 | 580 | 7 | 38.1 | 20.1 |
| 03-06-2018 14:30 | 36.57 | 45 | 153 | 22.3 | 590 | 4.3 | 37.9 | 30.4 |
| 03-06-2018 14:45 | 27.83 | 45 | 153 | 20.8 | 600 | 3.9 | 37.7 | 37.4 |
| 03-06-2018 15:00 | 29.02 | 45 | 153 | 23 | 610 | 4.1 | 37.9 | 45 |
| 03-06-2018 15:15 | 31.69 | 49 | 161 | 23.2 | 590 | 3.9 | 38.1 | 14.1 |
| 03-06-2018 15:30 | 32.45 | 49 | 161 | 21.5 | 590 | 4.2 | 37.8 | 19.8 |
| 03-06-2018 15:45 | 36.68 | 49 | 161 | 22.8 | 590 | 5 | 38 | 58.7 |
| 03-06-2018 16:00 | 27.18 | 49 | 161 | 21.4 | 580 | 5.2 | 38.1 | 24.1 |
| 03-06-2018 16:15 | 27.07 | 48 | 177 | 21.7 | 570 | 5.4 | 37.7 | 21.4 |
| 03-06-2018 16:30 | 27.98 | 48 | 177 | 24 | 570 | 5.7 | 38.1 | 22.1 |
| 03-06-2018 16:45 | 38.64 | 48 | 177 | 21.1 | 590 | 6 | 37.6 | 19.9 |
| 03-06-2018 17:00 | 39.9 | 48 | 178 | 21.4 | 590 | 6 | 37.5 | 13.9 |
| 03-06-2018 17:15 | 43.06 | 51 | 194 | 20.6 | 580 | 6.2 | 37.6 | 12.6 |
| 03-06-2018 17:30 | 27.39 | 51 | 194 | 20.6 | 600 | 6.2 | 37.6 | 20.6 |
| 03-06-2018 17:45 | 15.83 | 51 | 194 | 21.5 | 600 | 6.6 | 37.7 | 23.3 |
| 03-06-2018 18:00 | 21.56 | 51 | 194 | 21.7 | 610 | 6.4 | 37.5 | 18.2 |
| 03-06-2018 18:15 | 29.83 | 46 | 189 | 21.7 | 600 | 6.5 | 37.7 | 27.7 |
| 03-06-2018 18:30 | 27.71 | 46 | 189 | 21.8 | 610 | 7.3 | 37.5 | 51 |
| 03-06-2018 18:45 | 22.41 | 46 | 189 | 22.1 | 630 | 7.2 | 37.8 | 46.3 |
| 03-06-2018 19:00 | 18.49 | 46 | 191 | 21.2 | 630 | 6.7 | 39 | 71.2 |
| 04-06-2018 07:15 | 19.46 | 33 | 141 | 30.8 | 640 | 8.6 | 37.8 | 16.2 |
| 04-06-2018 07:30 | 18.92 | 32 | 141 | 31 | 650 | 8.8 | 38.6 | 15 |
| 04-06-2018 07:45 | 30.69 | 32 | 141 | 31.8 | 660 | 7.5 | 40.3 | 17.3 |
| 04-06-2018 08:00 | 4.74 | 32 | 142 | 31.5 | 670 | 6.9 | 38.6 | 16.8 |
| 04-06-2018 08:15 | 27.27 | 48 | 173 | 31.8 | 660 | 5.1 | 39.2 | 17.7 |
| 04-06-2018 08:30 | 19.69 | 49 | 173 | 30 | 660 | 3.3 | 38.2 | 14 |
| 04-06-2018 08:45 | 42.04 | 49 | 173 | 29.6 | 670 | 2.7 | 39.5 | 12.2 |
| 04-06-2018 09:00 | 41.06 | 49 | 173 | 28.7 | 670 | 1.4 | 38 | 20.5 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 04-06-2018 09:15 | 37.55 | 50 | 168 | 27.8 | 660 | 1.7 | 38 | 18.1 |
| 04-06-2018 09:30 | 51.74 | 50 | 168 | 29.1 | 680 | 1.8 | 39.4 | 16.5 |
| 04-06-2018 09:45 | 29.14 | 50 | 168 | 27.8 | 690 | 1.9 | 38.7 | 21.1 |
| 04-06-2018 10:00 | 47.13 | 50 | 169 | 25.9 | 690 | 1.9 | 38.1 | 15.7 |
| 04-06-2018 10:15 | 64.43 | 57 | 182 | 27.6 | 690 | 2.2 | 38.9 | 18.8 |
| 04-06-2018 10:30 | 44.41 | 57 | 182 | 26.6 | 700 | 2.3 | 38.4 | 21.4 |
| 04-06-2018 10:45 | 42.01 | 57 | 180 | 26.3 | 700 | 2.4 | 38.3 | 17 |
| 04-06-2018 11:00 | 59.49 | 57 | 183 | 26 | 700 | 2.6 | 38.3 | 12.6 |
| 04-06-2018 11:15 | 51.11 | 49 | 209 | 25.2 | 680 | 2.8 | 38.1 | 15.3 |
| 04-06-2018 11:30 | 48.32 | 49 | 209 | 24.7 | 680 | 3.1 | 39.8 | 16.9 |
| 04-06-2018 11:45 | 41.48 | 49 | 209 | 25.6 | 680 | 3.1 | 39.1 | 22.8 |
| 04-06-2018 12:00 | 42.26 | 49 | 209 | 24.3 | 680 | 3.2 | 38.1 | 16.8 |
| 04-06-2018 12:15 | 46.73 | 56 | 232 | 23.1 | 660 | 3.3 | 39.1 | 15.8 |
| 04-06-2018 12:30 | 43.02 | 57 | 232 | 25.4 | 680 | 2.8 | 38.6 | 20 |
| 04-06-2018 12:45 | 46.32 | 57 | 232 | 27 | 700 | 2.3 | 38.3 | 13.2 |
| 04-06-2018 13:00 | 35.25 | 57 | 232 | 26 | 690 | 2.1 | 38.1 | 14.9 |
| 04-06-2018 13:15 | 60.63 | 94 | 232 | 25.7 | 660 | 2.1 | 38.4 | 15.1 |
| 04-06-2018 13:30 | 62.09 | 96 | 232 | 26.4 | 660 | 2.2 | 38.8 | 18.9 |
| 04-06-2018 13:45 | 63.58 | 96 | 232 | 28.4 | 660 | 2.3 | 38 | 25.4 |
| 04-06-2018 14:00 | 71.87 | 96 | 233 | 27.7 | 670 | 2.3 | 38.4 | 19.7 |
| 04-06-2018 14:15 | 34.4 | 62 | 270 | 25.7 | 630 | 2.4 | 38.5 | 20.1 |
| 04-06-2018 14:30 | 33.84 | 60 | 270 | 24.9 | 630 | 2.8 | 39 | 25.9 |
| 04-06-2018 14:45 | 34.98 | 60 | 270 | 24.9 | 630 | 3.2 | 38.3 | 26.8 |
| 04-06-2018 15:00 | 48.3 | 60 | 281 | 26.6 | 680 | 3.4 | 38.6 | 29.3 |
| 04-06-2018 15:15 | 61.51 | 74 | 585 | 24.8 | 670 | 3.6 | 38.4 | 18.2 |
| 04-06-2018 15:30 | 63.33 | 75 | 585 | 23.8 | 670 | 3.8 | 39.1 | 18.8 |
| 04-06-2018 15:45 | 40.28 | 75 | 585 | 24.1 | 680 | 3.9 | 38.3 | 23.1 |
| 04-06-2018 16:00 | 23.29 | 75 | 577 | 24.5 | 670 | 4 | 38.2 | 13.7 |
| 04-06-2018 16:15 | 23.68 | 56 | 268 | 22.6 | 650 | 4.4 | 38.1 | 15.8 |
| 04-06-2018 16:30 | 35.67 | 55 | 268 | 23.2 | 670 | 4.6 | 38.5 | 19.3 |
| 04-06-2018 16:45 | 33.13 | 55 | 268 | 21.7 | 680 | 4.9 | 38.3 | 20.5 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 04-06-2018 17:00 | 26.79 | 55 | 270 | 24.4 | 670 | 5.3 | 38.7 | 23.9 |
| 04-06-2018 17:15 | 23.31 | 58 | 391 | 22.6 | 660 | 4.9 | 38.1 | 33.3 |
| 04-06-2018 17:30 | 34.21 | 58 | 391 | 22.2 | 660 | 5 | 37.8 | 38.1 |
| 04-06-2018 17:45 | 26.08 | 55 | 268 | 21.7 | 680 | 4.9 | 38.3 | 20.5 |
| 04-06-2018 18:00 | 55.63 | 58 | 388 | 21.5 | 650 | 5.2 | 39.4 | 69.9 |
| 04-06-2018 18:15 | 8.3 | 56 | 308 | 22.9 | 640 | 4.1 | 37.5 | 53.5 |
| 04-06-2018 18:30 | 31.82 | 56 | 308 | 24.7 | 640 | 3.3 | 38.9 | 81.8 |
| 04-06-2018 18:45 | 23.31 | 58 | 391 | 23.3 | 670 | 5.1 | 38 | 53 |
| 04-06-2018 19:00 | 48.04 | 56 | 307 | 24.1 | 620 | 3.1 | 37.5 | 61 |

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