Air Quality Assessment and Source Apportionment Study in Firozabad

Sponsor: District Magistrate, Firozabad, Uttar Pradesh

CSIR-National Environmental Engineering Research Institute (CSIR-NEERI), Nagpur - 440 020

April 2016

Air Quality Assessment and Source Apportionment Study in Firozabad

Sponsor

District Magistrate,
Firozabad, Uttar Pradesh

CSIR-National Environmental Engineering Research Institute (CSIR-NEERI),

Nagpur - 440 020

April 2016

FOREWORD

Firozabad is designated as the Glass City of India. It is located 45 km East of Agra which produces diverse glass items (such as automobile headlamp cover, vacuum glass refills, laboratory & scientific glassware, bangles, decorative pieces, light shades and chandeliers etc.). The production accounts for 70% of the total glass produced in the small scale sector in India generating employment to more than 150,000 people. The glass city falls within the Taj Trapezium Zone (TTZ), and is declared as air pollution protected area by Ministry of Environment and Forests, Government of India (MoEF, GOI).

As per the directions of the TTZ authority, the Firozabad Administration through District Magistrate approached the CSIR-National Environmental Engineering Research Institute (CSIR-NEERI), Nagpur to conduct a study to assess the present ambient air quality of Firozabad area and source apportionment for development of air quality management plan.

This report presents the status of ambient air quality of Firozabad area, major emission sources through receptor modelling and dispersion modelling to assess plausible impact. An effective Air Environment Management Plan (AEMP) is recommended to control/mitigate air emissions from various activities viz. emissions from glass industries, vehicular emissions, agricultural and domestic burning.

The cooperation and assistance rendered by District Industries Centre, Firozabad, staffs from Regional Office, Uttar Pradesh Pollution Control Board (UPPCB), and Firozabad are gratefully acknowledged. The trust reposed by Office of District Magistrate, Firozabad in the Institute through this assignment is also acknowledged.

Nagpur
16/04/2016

(Tapas Nandy)
Acting Director

PROJECT PERSONNEL

PROJECT GUIDE

Dr. S. R. Wate

Ex Director, CSIR-NEERI

PROJECT COORDINATOR

Er. (Mrs.) Padma S. Rao

PROJECT LEADERS

Dr. (Mrs.) V. V. Khaparde

Dr. Anirban Middey

Dr. Neelkamal

TEAM MEMBERS

Scientist

Er. K.V. George, Er. Anil D. Bhanarkar,

Dr. (Mrs.) Asha Lalwani, Er. (Mrs.) Papiya Mandal,

Project Assistant

Miss. Swati A.Tandekar, Miss.Sunita J. Uikey

Mr. Pankaj Kaware, Mr. Swapnil Raut, Er. M.N.V. Anil, Miss Shilpa Kadu

Contents

List of Tables

List of Figures

Executive Summary

Firozabad city, famous for its glass industry is located in North Central India in Western Uttar Pradesh. It is an industrial city and is well known for its beautiful bangles and other glass products. The city meets 70% requirement of the country's different glass items. The glass city falls within the Taj Trapezium Zone (TTZ). This area is located in Agra-Mathura region and declared as air pollution protected area by Ministry of Environment and Forests, Government of India (MoEF, GOI).

1. Project Proposal

In view of the directions given by TTZ authority, the Firozabad Administration through their District Magistrate approached CSIR-National Environmental Engineering Research Institute (CSIR-NEERI), Nagpur to conduct a study that establishes the ambient air quality and further source apportionment of Firozabad area. It is proposed to carry out ambient air quality monitoring and source apportionment study in Firozabad region to arrive at the following:

- Comparison of present air pollution level in Firozabad with that of 1993, when glass industry was using coal/coke as fuel.
- To identify and quantify the major air pollution emission sources in Firozabad using emission inventory and source apportionment tools.
- To determine the impact of emission from Firozabad on Taj Mahal, if any.
- Study the possibility of reducing air pollution in Firozabad region with appropriate source control/air quality management approach.
- During the course of the study, any other matter related to the present scenario will also be addressed.

2. Study Area (Area of TTZ falling within Firozabad District)

Firozabad city is 44 km from Agra and around 240 km away from Delhi, at the Northern edge of the Deccan Plateau, at 27°09′N 78°24′E. It is located 164 meters (540 ft)\ above sea level. The city is spread in 21.35 km2 area with a population of 601970 persons having 42 wards as per 2011 census. The city is well connected by road (Delhi – Howrah National Highway) and Railways through Main Line. The district is bounded on the North by Etah district, on the East by Etawah and Mainpuri district and on the South- West by Agra district. The whole district is a vast level plain. Yamuna, Sirsa & Sengar Rivers are flowing in the south of the district.

3. Methodology

The study begun with preliminary site survey and logistic generation followed by site selection for monitoring. Three sites were selected and at each site, gaseous parameters, PM_{10} and $PM_{2.5}$ were monitored. The monitoring was carried out during post monsoon period. A meteorological station was set up at one of the sites. Parallel to the air quality monitoring, emission inventory of the study area with respect to point sources was carried out, which will act as a complementary tool to source apportionment.

The ultimate objective was delineation of air quality management plan that primarily requires knowledge of ambient air quality status and emission loads. These two objectives were achieved through monitoring of air pollutants at select locations using various instruments/gadgets for different pollutants and carrying out emission inventory through primary and secondary data collection. In order to exercise the source control measures, it is necessary to know the contribution from each type of source. This was carried out by receptor modelling (source apportionment). The work component are divided into four parts namely ambient air quality monitoring, emission inventory, source apportionment analysis and finally delineating an air quality management plan based on the data collected during the study.

(a) Ambient Air Quality (AAQ) Monitoring

Air Quality Monitoring was performed by NEERI at 3 locations which are Raja-ka-Tal (Industrial area), Tilaknagar (Residential area) and DIC (Mixed area). Additional monitoring was also carried out by GRIMM portable aerosol spectrometer to check diurnal variation of PM_{10} and $PM_{2.5}$ particulates.

Some of the important air pollutants covered in this study are particulate matter (PM_{10}, $PM_{2.5}$), sulphur dioxide (SO_2), nitrogen dioxide (NO_2), ammonia (NH_3), carbon monoxide (CO), benzene (C_6H_6) and ozone (O_3). Crustal elements Fe, Al, Mg, K, Ca, Si, other elements (Co, Cr, Cu, Mn, Ni, Ti, V, Sr, Ba, Na, Pb, Al, Hg, Zn, Cd, As), non-metals (Se, S), secondary inorganic aerosol (SIA), carbonaceous matter (organic and elemental carbon) and poly nuclear hydrocarbons (BaP) were also characterized in PM_{10}.

Average PM_{10} and $PM_{2.5}$ concentrations at all the sites were exceeded by 1.6 to 2.2 times to that of daily average of PM_{10} (100 μg/m3) and by 1.2 to 1.4 times to that of daily average of $PM_{2.5}$ (60 μg/m3) of Indian National Ambient Air Quality Standard (NAAQS), guidelines promulgated by CPCB respectively (Ref. Table 3.6.5). Higher concentration levels were found at DIC (site located at downwind during study period) followed by Tilak Nagar and then by industrial area (Table 3.2.3a). Average concentrations of SO_2, NO_2, NH_3, CO and O_3 at all the sites were much below the NAAQS regulatory limit whereas benzene levels are exceeding the NAAQS limit at all the sites.

The average concentration of Pb was found to be well below the NAAQS limit of 1 μg/m^3 (24hr average) at all the sites. Arsenic (As) detected in PM_{10} at all the sites and levels were exceeding the NAAQS limit of 6 ng/m^3 (annual average) except at Raja-ka-Tal. The average concentration of Ni was exceeding the prescribed limit of 20 ng/m^3 (annual average) at DIC. Levels of BaP are also exceeding the NAAQS limit at all the sites.

Present study shows that the levels of SO_2 are decreased drastically by two times while levels of NO_2 are increased by 1.4 to 2.6 times when compared with the levels of SO_2 and NO_2 measured in 1993 (when the coal was in use).

(b) Emission Inventory and Source Dispersion Modelling

Emission inventory (EI) is a tool for identifying the sources of pollution and quantifying emissions of pollutants. The study involved preparation of emission inventory for stack (point) and vehicular (line) sources. The data/information was obtained from the office of District, Firozabad and District Industry centre (DIC), Firozabad. All the available sources of primary as well as secondary data were referred. Appropriate methodologies/ techniques were adopted for the development of emission inventory.

In order to understand the movement of emission from the stack top, simulation of emitting plume is carried out using source dispersion model. State-of-the-art CALPUFF model is used for this purpose. Study domain of 100 km x 100 km, which covers the important places within Taj Trapezium Zone is constructed. The main places covered in the study domain are Bharatpur, Mathura, Agra, Hathras and Firozabad. Meteorological data of the complete study area at a resolution of 4 km x 4 km is prepared using prognostic model. The wind direction for February and July is towards Taj Mahal, the simulation is carried out for these two months and the resulting GLC of NO_x (Ref. Fig. 5.20 and 5.21 in Chapter 5). In both (February & July) the months, the wind is from two different directions thereby merging the isopleths. The isopleth indicates that the pollutants ceases within a very short distance from the cluster of sources and is not likely to reach Agra.

(c) Source Contribution (Apportionment) Analysis

The contribution of pollutants by various sources and their respective share with respect to ambient air quality in any given area can be assessed in two ways. One is through the calculation of emissions from various activities or source categories using emission inventory data and the other is the estimation of percent fraction contributed by different source categories to ambient air using receptor modelling.

In this study, receptor data includes chemical species concentration of particulate matter collected at three AAQ stations at Firozabad. Particulate matter collected from these sources is chemically analyzed for various species and signature of sources was identified. The chemical species data generated for PM_{10} of pollution sources is called source signature profile. As indicated above, the contribution of pollutants from different sources is carried out by receptor modelling through appropriate markers using Chemical Mass Balance (CMB) model. The contribution of pollutants from different sources estimated for any sampling (receptor) site would help in preparing the strategy for pollutant control. Source apportionment study of PM_{10} showed that at Raja ka Taal the contribution of glass industries (40%), waste burn (21%) and DG set emission (17%); at Tilak Nagar: road dust (33%), domestic burning (25%) and glass industries (10%) and at DIC: waste burn (49%), road dust (15%) and glass industry (12%) were observed. The overall source contribution of glass industries to PM_{10} is found to be 20%.

4. Environmental Management Plan

- The best available technique such as flue gas recirculation (FGR) and low NOx burners and bag filter system in conjunction with a dry or semi-dry acid gas scrubbing system is recommended to be adopted for control of dust emission from furnaces in the glass industry.
- Two post combustion technologies recommended for application to natural gas-fired boilers to reduce NOx emissions are selective non-catalytic reduction (SNCR) and selective catalytic reduction (SCR). The SNCR system injects ammonia (NH_3) or urea into combustion flue gases (in a specific temperature zone) to reduce NOx emission (Ref. US EPA document: AP42, Fifth Edition, vol-1, chapter-1, 2009).
- Periodic performance evaluation of control systems should be done and the efficacy of efforts made towards pollution control should be evaluated through independent agency on regular basis.
- Apart from the continuous monitoring of pollutants at source, regular ambient air monitoring should be carried to assess the level and tracking the reductions in pollutants levels in areas that may be impacted due to industries.

- Vehicle movement related re-suspension of dust can be reduced by having better paved roads and plantation along the roadsides. It is recommended to improve the traffic management.

In order to control/mitigate air emissions from various activities in glass industries, and to improve air quality in surrounding area, the proposed measures suggested based on the study finding needs to be implemented.

Conclusion

The scope of the present study is addressed to assessment of present air quality and source apportionment of particulate matter including metal and organics to depict the dominant contributories in air pollution from various sectors.

Presently the levels of particulates matter are exceeding the norms where the contribution of secondary inorganic aerosols are emerging. NO_x, VOCs, CO, CO_2 and trace SO_x, emit from CNG based glass industry, transport sector (vehicular activities), fossil fuel burning (agricultural and domestic burning) etc. Some of these pollutants also contribute to particulates formation. In order to control/mitigate air emissions from various activities in the study area, the measures recommended in the management plane based on the study data needs to be implemented.

The predicted isopleth of source dispersion model (CALPUFF model) shows that the pollutants ceases within a very short distance from the cluster of sources in Firozabad and is not likely to reach Taj Mahal, Agra.

Chapter I:

1 INTRODUCTION

1.1 Project Background

Firozabad, a city famous for its glass industry is located in North Central India, in Western Uttar Pradesh. It is an industrial city and is well known for its beautiful bangles and other glass products. City meets the 70% requirements of the country for different glass items.

Since Mughal era, rejected glass articles brought to India by invaders, were collected and melted in locally made furnaces at **Firozabad called "Bhainsa Bhatti''**. This practice is still continued and has given Firozabad city, the distinction of Glass Manufacturing Hub.

The glass city falls within the Taj Trapezium Zone (TTZ). This area is in Agra-Mathura region and declared as air pollution protected area by Ministry of Environment and Forests, Government of India (MoEF, GOI). TTZ comprises over 40 protected monuments including three World Heritage Sites — the Taj Mahal, Agra Fort and Fatehpur Sikri. Taj Mahal is one of the Seven Wonders of the World notified in the World Heritage list of the United Nations Educational, Scientific and Cultural Organization (UNESCO). It is located in Agra, Uttar Pradesh. Emperor Shahjahan built Taj Mahal in 17th Century A.D. in memory of his beloved wife, Mumtaj. This trapezium-shaped area of 10,400 sq.km around the Taj Mahal have Agra, Firozabad, Mathura (all in UP) and Bharatpur in Rajasthan as its corner cities. (**Figure 1.1**) This *area is bounded by Longitude 77⁰15'E on the West, 78⁰30'E on the East and lines joining Latitude 27⁰45'N to Latitude 27⁰30'N on the North and Latitude 26⁰45' to 27⁰00'N on the South.*

Figure 1.1 TTZ area around the Taj Mahal and Cities Agra, Firozabad, Mathura (all in UP) and Bharatpur in Rajasthan as its corner cities.

Earlier wood was used as a fuel during the old days which was later changed to coal and coke. Emissions from coal/coke burning were ignored until early nineties however, industrialization and urban growth in TTZ region has endangered the world famous Taj Mahal and other historical monuments from the ever increasing environmental pollution. The concern for protection of environment around Taj Mahal has raised objection to the large amount of coal burning in the furnaces of Glass manufacturing units at Firozabad.

Litigation followed and in a landmark judgment Honble' Supreme Court passed an order Dt. 30-12-1996 (writ petition –civil No. 13381 of 1984) prohibiting use of coal/coke and directed use of cleaner fuel i.e. Natural Gas. At present, 199 Glass-units are operating on Natural Gas and remaining 30 to 40 units are awaiting release of Gas supply.

Uttar Pradesh State Pollution Control Board (UPSPCB) is monitoring 3 air quality parameters. Respirable Suspended Particulate Matter (RSPM), Sulphur Dioxide (SO_2) and Nitrogen Dioxide (NO_2) at 3 stations in Firozabad. It is reported that SO_2 is below the stipulated regulatory norms, while NOx and RSPM are above the regulatory norms. Following the practice of monitoring the environmental status of TTZ, the committee had a meeting on May 6, 2015, wherein issue of releasing gas supply to 30 to 40 glass manufacturing units was considered. Matter of air pollution levels in Firozabad was also discussed and it was decided to ascertain sources of increase of air pollution before taking any decision on the matter of releasing gas supply to the new glass units. Directions have been given by TTZ authority for study of sources of increase in air pollution specially NOx and RSPM to make the contribution of industry and other sources clear.

In view of the directions given by TTZ authority, the Firozabad Administration through their District Magistrate approached National Environmental Engineering Research Institute (NEERI), Nagpur *to conduct a study that establishes the air quality and further source apportionment of Firozabad area (June 2015).*

1.2 Taj Trapezium Zone (TTZ): Status and Chronology of Events

A decision was taken in 1973 by GOI to set up a Petroleum Oil Refinery at Mathura under the Indian Oil Corporation of India. Concerns were expressed about the possible undesirable effects on the historic monuments in the Agra-Mathura region, from the gaseous emissions to be discharged from the Refinery. This was the first episode to raise concern regarding the environmental safety of the Taj Mahal.

In 1974, Expert Committee (EC) constituted by GOI under the Chairmanship of Dr. S. Varadarajan, concluded that there was no harm to the Taj from the proposed Mathura Refinery.

Based on the recommendations in the report of the EC on the Environmental Impact of Mathura refinery, Vardarajan Committee (1978) recommended

- Closure of two thermal power plants in Agra
- Use of diesel in shunting yards in order to stop the use of steam locomotives
- Shifting of foundries from Agra City to an area south east of the Taj Mahal.

In the meantime, the work on the Mathura Refinery started. The disapproval of the conclusions of the Varadarajan Committee in 1979 necessitated the setting up of a joint Committee of Parliament under the Chairmanship of Dr. Karan Singh. This Committee suggested shifting of most polluting units to Etawah Region.

Subsequently, the GOI constituted a High Power Committee (HPC) and an Expert Group (EG) to assist the HPC to make a detailed and in depth study of the whole problem and tó make suitable recommendations. The Chairman of Central Pollution Control Board (CPCB) was appointed as the Chairman of the EG. Thus, in 1881, the Government closed two thermal power plants, started the use of diesel in shunting yards resulting in stoppage the use of steam locomotives at Agra and initiated the monitoring of Ambient Air Quality with the involvement of Archeological survey of India (ASI), CPCB (both continue monitoring till date) and NEERI at Taj Mahal. The CPCB demarcated the Taj Trapezium Zone in 1981-1982.

In 1984, Mr. M.C. Mehta filed a writ petition before the Supreme Court against GOI, Mathura Refinery, U.P. Govt. and other Govt. departments and requested to take suitable measures to conserve the Taj Mahal from threat of air pollution caused by Mathura Refinery. For this, the petition suggested the shifting of Mathura Refinery that started in 1983.

Recognizing the need to preserve precious monuments like Taj Mahal from air pollution point of view, MoEF, GOI initiated another study by NEERI in 1993. NEERI's report suggested a slight modification of the TTZ boundary and recommended shifting of small-scale industries out of the TTZ. Guided by this report, the Supreme Court asked industries in Agra to give information relating to shifting vide their order of 11.04.1994. Sensing that such a step would kill the small industries, directly affecting 305 entrepreneurs, 57,800 workers and their families, the Supreme Court disregarded the study done by NEERI in February 1994 and directed GOI, Ministry of Environment to undertake a new study on air pollution in the TTZ. Varadarajan Committee was appointed once again by the GOI in 1994 with the following TOR:

- To undertake survey of the Taj Trapezium and sources of pollution
- To identify the polluting industries
- To suggest measures to control pollution, which cause danger to the Taj
- Specific activities of monitoring, analysis and data etc. by Engineers India Ltd., who will take the assistance of specialized agencies of Council for Scientific and Industrial Research
- The Committee will examine all reports of preceding committees
- The Committee will also suggest an ongoing institutional mechanism to permanently monitor changes of pollutants in the Taj Trapezium and advice corrective action

The CPCB delineated the TTZ, based on the weighted mean wind speed in twelve directions from Agra to Mathura and Bharatpur. The boundaries of the zone were made keeping in mind the possible effect of pollution sources in this zone on the critical receptor – the Taj Mahal. This area was declared as an "Air Pollution Protection Area".

1.3 Hon'ble Supreme Court Orders (Air Pollution Control)

The Supreme Court of India delivered a ruling on December 30, 1996 regarding industries covered under the TTZ, in response to a PIL seeking to protect the Taj Mahal from environmental pollution. It banned the use of coal/coke in industries located in the TTZ with a mandate for switching over from coal/coke to natural gas, and relocating them outside the TTZ or shutting down. Further, MoEF, GOI in the year 1999 notified Taj Trapezium Zone Pollution (Prevention & Control) Authority, Agra for protection and improvement of the environment in the TTZ area.

TTZ authority looks after activities leading to environmental pollution within TTZ area. The MoEF set up the TTZ authority in 1999 for protection and improvement of environment in TTZ area. The TTZ authority shall, within the geographical limits of Agra Division, in the TTZ one in the State of Uttar Pradesh, have the power to:

– monitor progress of the implementation of various schemes for protection of the Taj Mahal and programmes for protection and improvement of the environment in the above said area;

– exercise powers under section 5 of the said act;

- take all necessary steps to ensure compliance of specified emission-standards by motor vehicles and ensuring compliance of fuel quality standards;
- deal with any environmental issue which may be referred to it by the Central Government or the State Government of Uttar Pradesh relating to the above said area;

The projects of Electric Power Supply Improvement, Solid Waste Management, Sewerage, Forestation etc. are being implemented under Taj Protection Mission

1.4 Present Study at Firozabad

In view of the directions given by TTZ authority, the Firozabad Administration through their District Magistrate approached National Environmental Engineering Research Institute (NEERI), Nagpur to conduct a study that establishes the ambient air quality and further source apportionment of Firozabad area.

1.4.1 Objective

It is proposed to carry out ambient air quality monitoring and source apportionment study in Firozabad region to arrive at the following:

➢ Comparison of present air pollution level in Firozabad with that of 1993, when glass industry was using coal/coke as fuel.

➢ To identify and quantify the major air pollution emission sources in Firozabad using emission inventory and source apportionment tools.

➢ To determine the impact of emission from Firozabad on Taj Mahal, if any.

➢ Study the possibility of reducing air pollution in Firozabad region with appropriate source control/air quality management approach.

➢ During the course of the study, any other matter related to the present case will also be addressed.

1.4.2 Scope of the Work

- The study region would be Firozabad city area wherein glass industries are concentrated.
- The monitoring stations will be identified after preliminary field-work of emission inventory with due consideration to the available logistic facility, which include power supply, safety and security of equipments and personnel.

- Regulatory Air Quality Parameters of 2009 with respect to PM_{10}, $PM_{2.5}$, SO_2 and NO_2 will be considered in the monitoring.
- Air Quality Monitoring during one season (either during post monsoon or during winter) will be carried out.
- Chemical speciation of particulate Matter (PM_{10}) will be carried out.
- Status of air quality in terms of SO_2, NO_2 and particulate matter (PM_{10} and $PM_{2.5}$) in the study area
- Source apportionment of PM_{10} for the study area.

1.4.3 Study Area (Area of TTZ falling within Firozabad District)

1.4.3.1 Geographical Characteristics

Firozabad city is 44 km from Agra and around 240 km away from Delhi, at the Northern edge of the Deccan Plateau, at 27°09′N 78°24′E. It is located 164 meters (540 ft)\ above sea level. The city is spread in 21.35 km^2 area with a population of 601970 persons having 42 wards as per 2011 census. The city is well connected by road (Delhi – Howrah National Highway) and Railways through Main Line. The district is bounded on the North by Etah district, on the East by Etawah and Mainpuri district and on the South- West by Agra district. The whole district is a vast level plain. Yamuna, Sirsa & Sengar Rivers are flowing in the south of the district.

1.4.3.2 Topo-Climatologically Characteristics

The climate of Firozabad is very dry. The temperature of the district varies from 2° C in winter to 47° C in summer. The wet session normally starts in the early of July month. The average rainfall is 751 mm. Climatically, Firozabad city falls under sub-humid climate, and about 90 percent of the rainfall takes place from June to September. The winter months are virtually dry.

1.5 Study Methodology

Keeping in view the scope of work agreed upon as per the TOR of the study, discussions were held with NEERI scientists and District Magistrate along with other stakeholders' of Firozabad Glass industries. Based on the information collected during 1994 study, 2013 study, air quality of Firozabad provided by DIC and proposed work plan, study carried out by NEERI Study Team in October 2015.

The air quality regulatory requirement of 1993 required monitoring of three parameters viz., SO_2, NOx and Suspended Particulate Matter (SPM). Subsequent improvement in the science and technology of air quality monitoring has helped in changing the regulatory parameters. For example, in 1994 air quality guidelines an additional parameter i.e., PM_{10} is also included for monitoring besides SPM. The next 2009 air quality regulatory requirement included measurement of $PM_{2.5}$ particulates.

The three PM size fractions viz., SPM, PM_{10} and $PM_{2.5}$ are indicators of air quality. However, lower size fractions are human health indicators and therefore given more prominence in monitoring. Particulates >$PM_{2.5}$ are considered to be originated from geological activity like mining, road dust resuspension etc. while $PM_{2.5}$ is considered to be emitted from combustion activities. Natural Gas combustion in glass furnaces mainly emit gaseous pollutants such as NO_2, CO_2 Some gaseous precursor pollutants are converted into in the sub-micron size particulates. With the current wisdom, SPM, which is below 100 μm does not have health implication, instead it is a nuisance and therefore usually reduced in urban area by tree plantation and paving of roadside. The SPM monitored during 1993 included emission from coal combustion, wind-blown dust and from unpaved road dust. Presently, SPM may be from increased anthropogenic activities such as construction activities, movement of vehicles, which may result in re-suspension of dust etc., and its value may exceed the 1993 values. If the present values are more than the 1993 value, it may be interpreted as emission from glass industry.

In this study, the resources are not used for monitoring SPM merely for sake of comparison with earlier (1993) measured values, instead it is used for continuous measurement of gaseous pollutants, which are the real indicators of emission from natural gas combustion like NO_2, hydrocarbon and its secondary product O_3.

The study begun with preliminary site survey and logistic generation followed by site selection for monitoring. One site on Government building was chosen for monitoring to ensure safety of the equipment. Other sites were identified based on the local conditions after the survey. At each site, besides gaseous parameters, PM_{10} and $PM_{2.5}$ were monitored. The monitoring was carried out during post monsoon period. A meteorological station was set up at one of the sites. Parallel to the air quality monitoring, emission inventory of the study area with respect to point sources was carried out, which will act as a complementary tool to source apportionment.

The ultimate objective was delineation of air quality management plan that primarily requires knowledge of ambient air quality status and emission loads. These two objectives were achieved through monitoring of air pollutants at select locations using various instruments/gadgets for different pollutants and carrying out emission inventory through primary and secondary data collection. In order to exercise the source control measures, it is necessary to know the contribution from each type of source. This was carried out by receptor modeling (source apportionment). The work component are divided into four parts namely ambient air quality monitoring, emission inventory, source apportionment analysis and finally delineating an air quality management plan based on the data collected during the study.

1.5.1 Ambient Air Quality Monitoring

Ambient air quality monitoring included both criteria pollutants monitoring as well as pollutants that are source specific. Ambient air quality standards of CPCB **(Annexure I)** were used to compare ambient air quality. Some of the important air pollutants covered in this study are particulate matter (PM_{10}, $PM_{2.5}$), sulphur dioxide (SO_2), nitrogen dioxide (NO_2), ammonia (NH_3), carbon monoxide (CO), benzene (C_6H_6), ozone (O_3) and poly aromatic hydrocarbons (BaP). Crustal elements Fe, Al, Mg, K, Ca, Si and other elements (Co, Cr, Cu, Mn, Ni, Ti, V, Sr, Ba, Na, Pb, Al, Hg, Zn, Cd, As and non-metals (Se, S), Secondary Inorganic Aerosol (SIA), carbonaceous matter were also characterized in PM_{10}.

Besides, the location of primary monitoring, meteorological data for the study area were also collected from the sites.

1.5.2 Emission Inventory

Emission inventory (EI) is a tool for identifying the sources of pollution and quantifying emissions of pollutants. The study involved preparation of emission inventory for stack (point), and vehicular (line) sources. The data/information was obtained from the office of District, Firozabad and District Industry Center (DIC), Firozabad. All the available sources of primary as well as secondary data were referred. Appropriate methodologies/ techniques were adopted for the development of emission inventory.

1.5.3 Source Contribution (Apportionment) Analysis

The contribution of pollutants by various sources and their respective share with respect to ambient air quality in any given area can be assessed in two ways. One is through the calculation of emissions from various activities or source categories using emission inventory data and the other is the estimation of percent fraction contributed by different source categories to ambient air using receptor modeling.

In this study, receptor data includes chemical species concentration of particulate matter collected at three AAQ stations at Firozabad. Particulate matter collected from these sources is chemically analyzed for various species and signature of sources was identified. The chemical species data generated for PM_{10} of pollution sources is called source signature profile. As indicated above, the contribution of pollutants from different sources is carried out by receptor modeling through appropriate markers using Chemical Mass Balance (CMB) model. The contribution of pollutants from different sources estimated for any sampling (receptor) site would help in preparing the strategy for pollutant control.

Chapter II: Meteorology

2.1 Meteorology of the Region

Meteorological data relevant from the air pollution studies point of view is being collected from various sources like reports from Hydromet division and Agricultural Meteorology Division of India Meteorological Department (IMD), New Delhi and Global gridded Climate Research Unit (CRU) data (**1980-2012**). The meteorological parameters explored are inclusive of wind speed (m/s), wind direction (deg), ambient temperature (℃), relative humidity (%) and rainfall (mm).

The selective information posed below gives elaborate historical monthly average weather conditions to appraise local climatology of Firozabad.

2.2 Analysis of Meteorological Data from secondary sources

Throughout year temperature over Firozabad varies from 10°C to above 37°C with minimum observed in winter months of December and January while maximum observed in summer months of April and May. Relative humidity resides on maxima during monsoon months and showed minima during summer months which lead to a dry summer experience in Firozabad.

Wind speed shows maxima during pre-monsoon months (summer) with maximum average wind speed of 15 km/hr and minimum observed during post monsoon (Oct, Nov) months. Wind directions vary season to season throughout the year. **Figure 2.2.3** represents seasonal variation of average wind directions over Firozabad. During winter, wind blowing from WNW, NW and E directions towards Firozabad, in summer, winds from WNW, W and NW dominate, in monsoon season SW and E wind prevail while in post-monsoon E and NNW winds are blowing towards Firozabad. Monthly average rainfall (mm) and average number of rain days in a month is shown in **Figure 2.2.4**. Majority of rainfall occurs during June to September with maximum number of rain days in August. Post-monsoon (Oct, Nov) and winter (Dec, Jan and Feb) seem to have negligible amount of rain with very less number of rainy days.

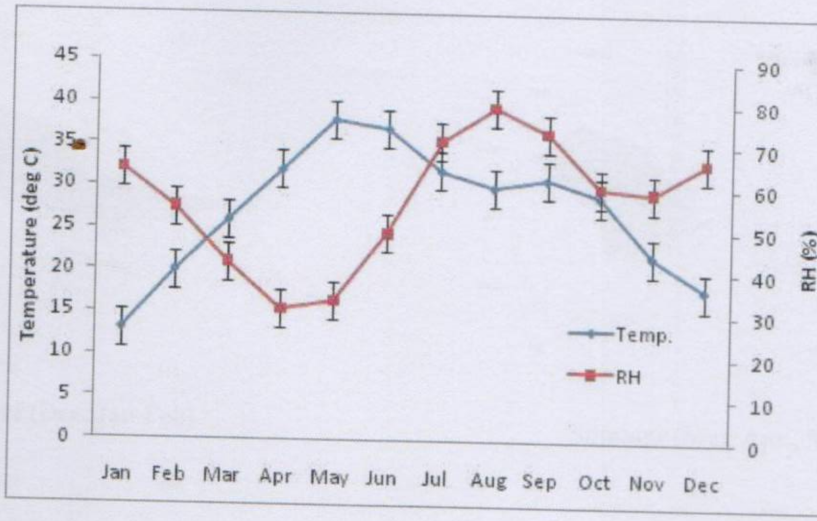


Figure 2.2.1: Monthly average temperature and relative humidity

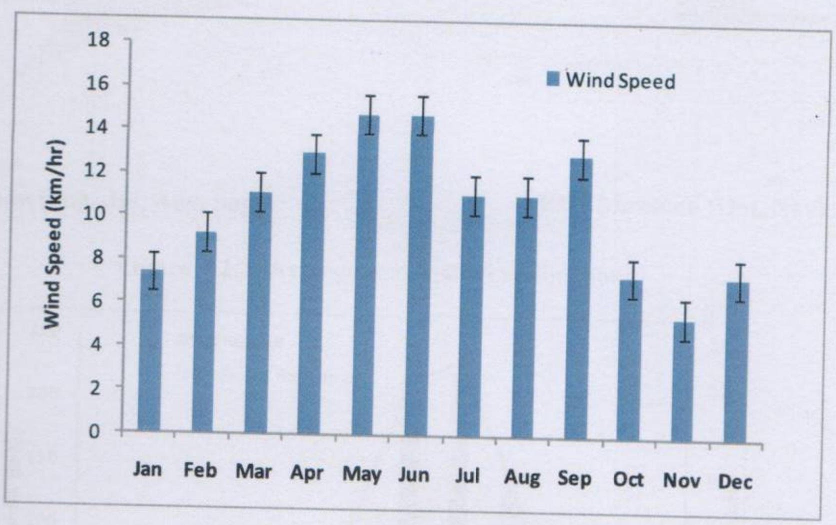
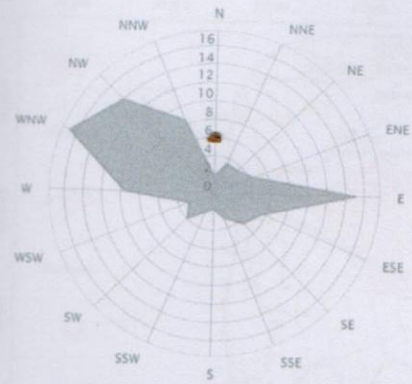
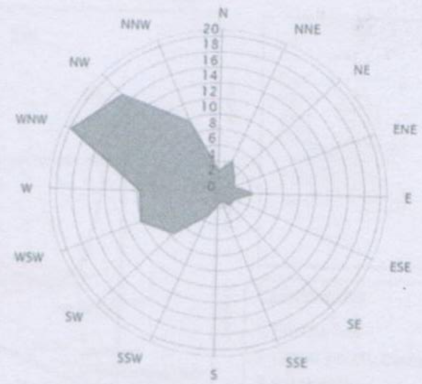


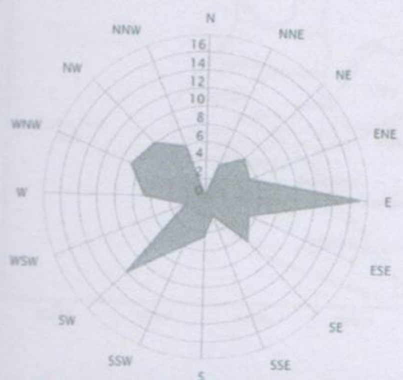
Figure 2.2.2: Monthly average wind speed



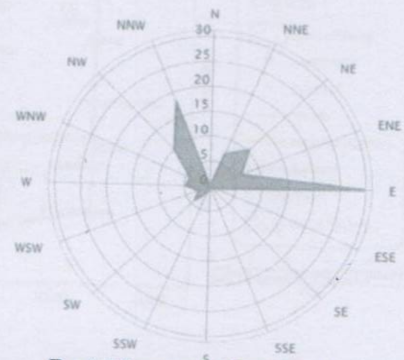
Winter (Dec, Jan Feb)



Summer (Mar, Apr , May)



Monsoon (Jun, Jul, Aug, Sep)



Post-Monsoon (Oct, Nov)

Figure 2.2.3: Average seasonal wind directions

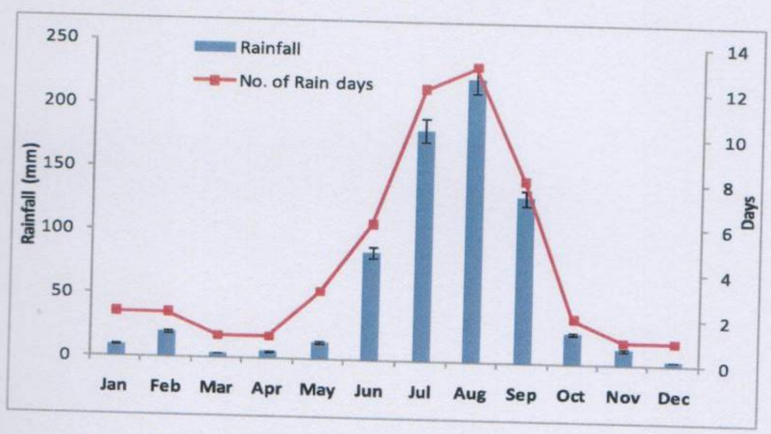


Figure 2.2.4: Monthly average rainfall and average number of rain days.

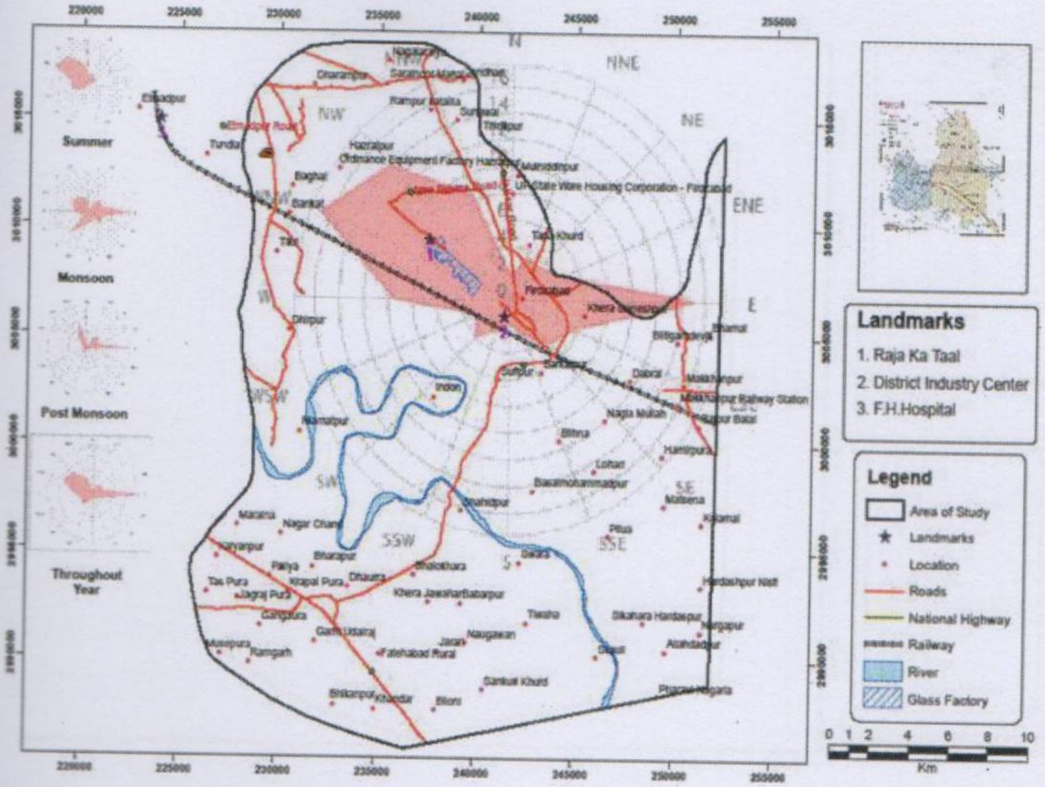


Figure 2.2.5: Wind direction pattern during winter season over the study area.

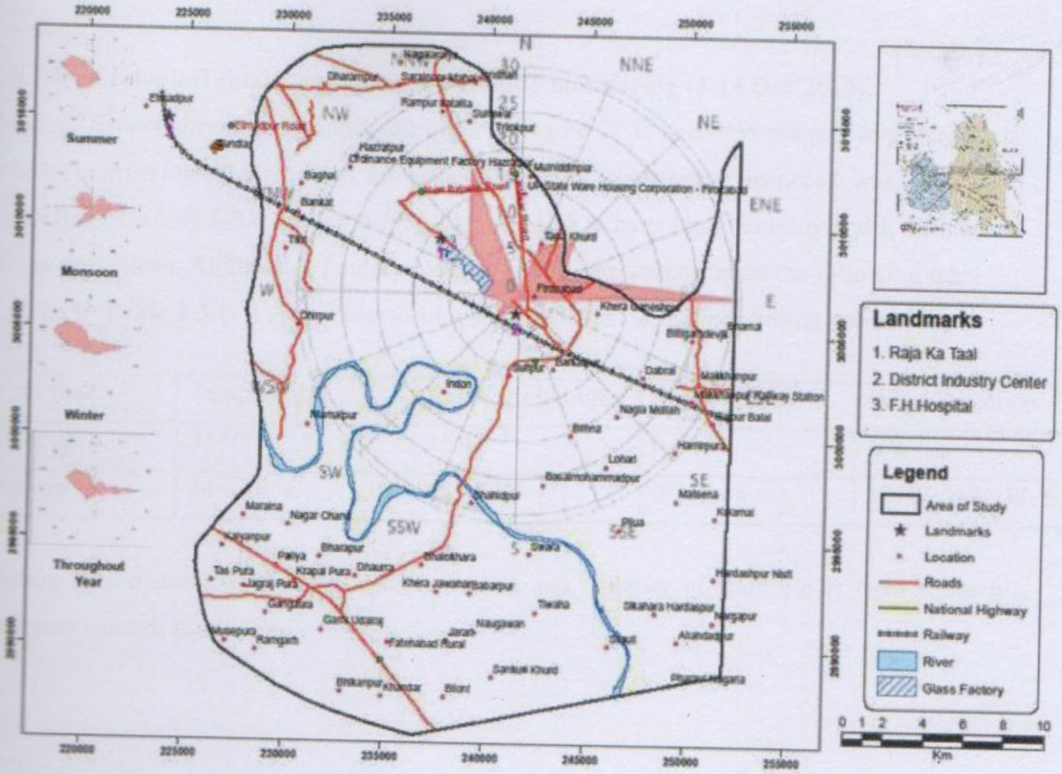


Figure: 2.2.6 Wind direction pattern during Post-Monsoon season over the study area.

2.3. Meteorological condition during Air quality monitoring (2-14 Oct'2015)

Average temperature and humidity are observed to be 31° C and 45% respectively during air quality monitoring at Firozabad. However maximum temperature recorded was 39° C and maximum humidity 87%. Early morning periods seem to have high humidity and it disappears as day progresses. All details of meteorological conditions are briefed in the following table

Table 2.3.1: Average Meteorological condition during monitoring period

Parameters	Temperature	Relative Humidity	Wind Speed	Wind Direction
Average	31 ^{0}C	45 %	0.5 m/s	NW
Range	24 – 39 ^{0}C	16 - 87%	0 - 3 m/s	NNW, NW, W, E, S

Almost 70% of total wind are in calm condition and majority of wind blows from westerly direction towards the station.

Chapter III: Air Quality Status

3.0 Air Environment

3.1 Introduction

Air quality management primarily requires establishing the interrelationships among air quality monitoring, emission inventory and meteorology of the study area. In order to understand ambient air quality status and check compliance of pollutant levels in ambient air with regulatory standards, air quality monitoring for various air pollutants is essential. Specific pollutants with recommended sampling and analysis protocol to check compliance of their levels in ambient air with regulatory standards is given in **(Annexure I)**.

Criteria pollutants (PM, SO_2, NO_2) are monitored to examine the influence of various anthropogenic sources on ambient air quality. PM_{10} was further characterized for lead (Pb), arsenic (As), nickel (Ni) and benzo a pyrene (BaP, $C_{20}H_{12}$). In addition, gaseous/vapour phase air pollutants such as ammonia (NH_3), carbon monoxide (CO), ozone (O_3) and benzene (C_6H_6) have also been monitored to get the preliminary information about their existing concentration levels in ambient air within the study area and to check compliance of the same in ambient air with regard to the regulatory standards.

Since the present study aims at source apportionment of pollutants to identify the contribution of different sources to PM_{10}, besides criteria pollutants, chemical constituents such as mineral matter, trace elements, organic matter (OM), elemental carbon (EC), and secondary inorganic aerosol (SIA) are also monitored to identify different sources.

3.2 Air Quality Monitoring Methodology

3.2.1 Sampling Sites

Air Quality Monitoring was performed by NEERI at 3 locations and the details of the locations are summarized below in **Table 3.2.1**. Air quality monitoring locations are Raja-ka-Tal (Industrial area), Tilaknagar (Residential area) and DIC (Mixed area). Additional monitoring was also carried out by GRIMM sampler to check diurnal variation of PM_{10} and $PM_{2.5}$ particulates. Monitoring locations are shown in **Fig 3.2.1**

Table 3.2.1: Details of Air Quality Stations in Firozabad

S. No.	Monitoring Site	Location	Site Description	(Latitude/Longitude)
1	DIC	Downwind	Mixed area (C)	27^0 9' 7.7" N / 78^0 23' 22.9" E
2	Tilaknagar	Downwind	Residential area (R)	27^0 08' 53.8" N / 78.24' 22.54" E
3	Raja-ka-Tal	Upwind	Industrial (I)	27^0 11' 04.4' N / 78^0 20' 58.5" E

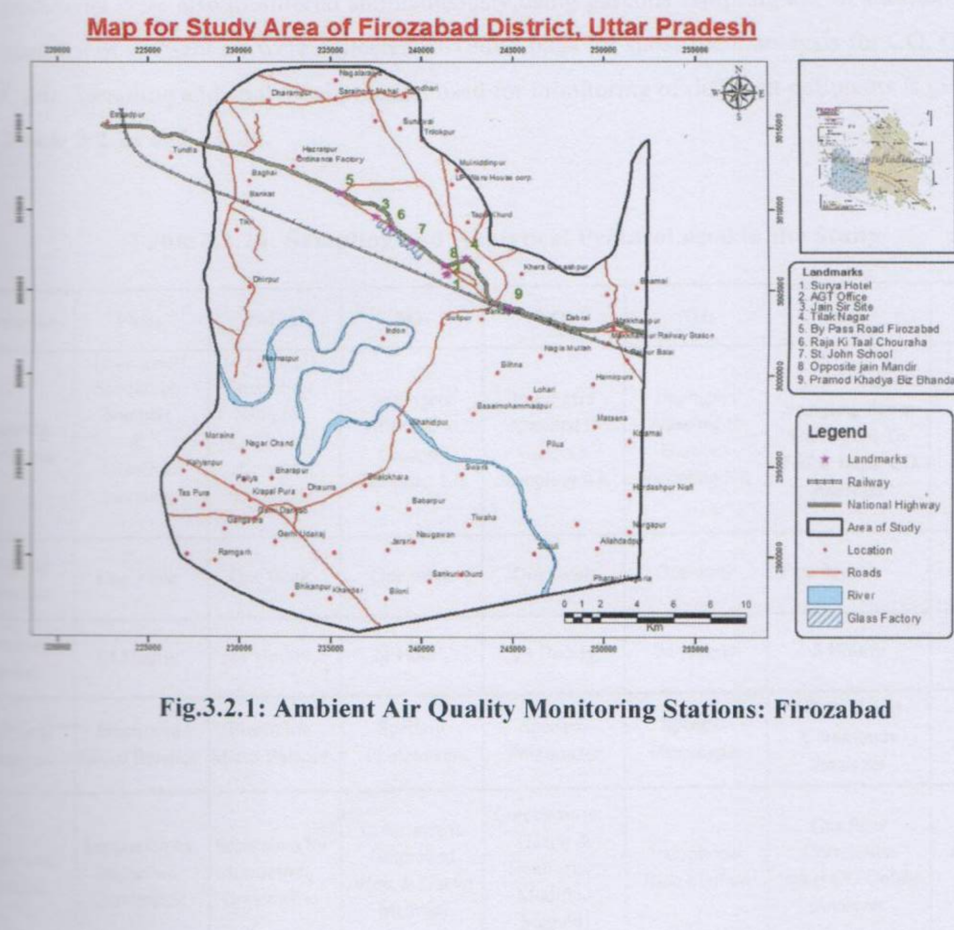


Fig.3.2.1: Ambient Air Quality Monitoring Stations: Firozabad

3.2.2 Monitoring Parameters

Parameters for monitoring were decided keeping in view the study objectives. Since the objective of study is regulatory compliance assessment besides source apportionment, monitoring included criteria pollutants such as PM_{10}, $PM_{2.5}$, SO_2, NO_2, NH_3, CO, O_3 and C_6H_6 in order to know the regulatory compliance status. PM_{10} was further characterized for Pb, As, Ni and BaP.

PM_{10} and $PM_{2.5}$ were collected on glass fibre filters (47 mm diameter) by a 4-channel speciation sampler (TSI-2300 four channel) as well as by using Airmetrics samplers. Gaseous pollutants were also monitored simultaneously using gaseous sampling kit, In addition, grab samples of ambient air were collected in Tedler bags for subsequent analysis for CO, O_3 and C_6H_6. Sampling and analytical protocol used for monitoring of different pollutants is given in **Table 3.2.2a** and **3.2.2b.**

Table 3.2.2a: Sampling and Analytical Protocol used in the Study

Particulars	PM_{10}	$PM_{2.5}$	SO_2	NO_2	NH_3	CO	Ozone
Sampling Instrument	(4 channel) Speciation Sampler & Airmetric samplers	(4 channel) Speciation Sampler & Airmetric samplers	Impingers Attached to Gaseous Sampling Kit	Impingers Attached to Gaseous Sampling Kit	Impingers Attached to Gaseous Sampling Kit	Low Volume Sampling Pump Connected To Tedlar Bags/ CO Analyzer	Low Volume Sampling Pump Connected To Tedlar Bags/ozone analyser
Sampling Frequency	One week	One week	One week	One week	One week	Two days	Two days
Sampling Period	24 Hourly	24 Hourly	24 Hourly	24 Hourly	24 Hourly	8 Hourly	8 Hourly
Analytical Instrument	Electronic Micro Balance	Electronic Micro Balance	Spectro-Photometer	Spectro-Photometer	Spectro-Photometer	NDIR Based Continuous Analyzer	Automatic Analyzer
Analytical Method	Separation by Impaction, Gravimetric	Separation by Impaction, Gravimetric	Colorimetric (Improved West & Gaeke Method)	Colorimetric (Jacob & Hochheiser Modified Method)	Indophenol Blue Method	Gas filter Correlation wheel CO Online Analyzer	UV Absorption, Online Analyzer
Minimum Detectable Limit	5 µg/m³	5 µg/m³	4 µg/m³	4 µg/m³	5 µg/m³	0.1 ppm	0.1 ppm

Table 3.2.2b: Sampling and Analytical Protocol used in the Study

Particulars	Ions	VOC (Benzene)	Trace elements	PAHs(BaP)	OC/EC
Sampling Instrument	Particulate Collected on Teflon filters	Low Volume Sampling Pump Connected to Tedlar Bags	Particulate Collected on Teflon Filter	Particulate Collected on Quartz Filter	Particulate Collected on Quartz Filter
Analytical Instrument	Ion Chromatograph	VOC Analyzer	ICP-OES	GC-MS	DRI Model 2001 Thermal and Optical Carbon Analyzer
Analytical Method	Extraction in DI Water : Sonication	GC-ATD	Acid Digestion	Extraction in Cyclo-hexane	IMPROVE thermal/optical reflectance (TOR) protocol
Minimum Detectable Limit	1.0 μg/m³	0.04 μg/m³	Ni : 0.00568 μg/m³ As : 0.00247 μg/ m³ Pb : 0.1940 μg/m³	B(a)P: 0.02 ng/m³	LOQ for OC and EC were 0.33 and 0.25 μg/m3

3.2.3 Monitoring and Analysis

Twelve major criteria parameters were sampled at three stations during the study period. **Fig. 3.2.3** shows one of the monitoring locations. PM_{10} and $PM_{2.5}$ samples on Teflon filters were analyzed for ions and elements while organics were analyzed in the particulates collected on quartz filters. Site-wise average and standard deviation values of measured pollutants concentrations are presented in **Table 3.2.3a and Table 3.2.3b** along with regulatory standards prescribed by CPCB to check the compliance.

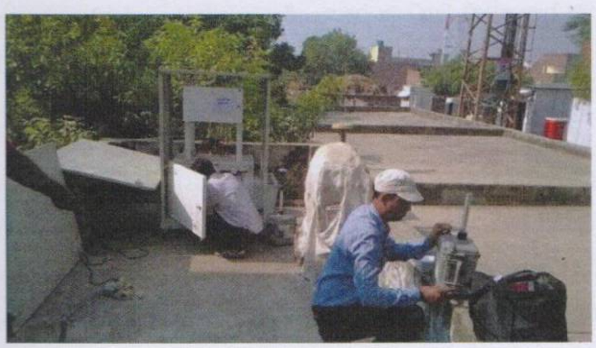


Figure 3.2.3. Sampling location at Firozabad

Table 3.2.3a: Statistical Summary of 24-hourly Average Values of PM_{10} and $PM_{2.5}$

Monitoring Site	PM_{10} Concentration (µg/m³)			$PM_{2.5}$ Concentration (µg/m³)		
	Avg	±SD	Range	Avg	±SD	Range
DIC	216.3	105.4	113.8-422.5	86.3	34.8	62.6-137.6
Tilak Nagar	170.3	47.6	119.7-249.5	77.2	12.7	32.0-100.3
Raja-ka-Tal	165.3	22.4	154.0-186.0	73.0	64.1	40.0-112.0
CPCB Standard	100			60		

At DIC, PM_{10} were in the range of 113-422.5 µg/m³ with mean of 216.3 ± 105.4 µg/m³. Average concentrations of PM_{10} was 170.3 (± 47.6 µg/m³) and ranged between 119.7 and 249.5 µg/m³ at Tilak Nagar while at Industrial site the average PM10 level was 165.3 (± 22.4) µg/m³ and their levels were varied between 154.0 and 186.0 µg/m3. Maximum average PM_{10} concentration (216.3 µg/m³) which is exceeded by 2.2 times of CPCB standard was observed at DIC, a site located to downwind direction to glass industry. The average PM_{10} concentration at Tilak Nagar (170.3 µg/m³) and Raja-ka-Tal (165.3 µg/m³) were also exceeded the value of CPCB standard. The standard deviation values ranged from 22. µg/m³ (at Raja-ka-Tal) to 105 µg/m³ (at DIC).

At DIC, $PM_{2.5}$ levels were in the range of 62.6-137.6 µg/m³ with mean 86.0 ± 34.8 µg/m3. Average concentrations of $PM_{2.5}$ was 77.2 (± 12.7 µg/m³) and ranged between 32.0 and 100.3 µg/m³ at Tilak Nagar while at Raja-ka-Tal, the $PM_{2.5}$ levels were 73.0 (± 64.1) µg/m³. Their levels were varied between 40.0 and 112.0 µg/m³. The average $PM_{2.5}$ concentration was also observed to be above the CPCB standard at all the sampling locations (Table 3.2.3a). Maximum average $PM_{2.5}$ concentration 86.3 µg/m³ was observed at DIC followed by Tilak Nagar (77.2 µg/m³) and Raja-ka-Tal (873.3 µg/m³). Similar trend was observed for $PM_{2.5}$ as that of the trend observed for PM_{10}.

Average percent contribution of $PM_{2.5}$ (which reaches up to alveolar region of the human respiratory tract) in PM_{10} was found to be 43 %. Diurnal variation of PM_{10}, $PM_{2.5}$ and PM_1 at industrial location and at traffic junctions on different days showed (**Fig - 3.2.1**) that the concentration levels are increased from 17:00 to 24:00 Hrs and 7:00 to 12:00 Hrs which may be attributed to increased anthropogenic activities.

Table 3.2.3b: Statistical Summary of 24-hourly Average Values of SO_2, NO_2 and NH_3

Monitoring Site	SO_2 Concentration ($\mu g/m^3$)			NO_2 Concentration ($\mu g/m^3$)			NH_3 Concentration ($\mu g/m^3$)		
	Avg	±SD	Range	Avg	±SD	Range	Avg	SD	Range
DIC	7	3	4 - 8	31.3	10.1	17.9-45.0	25.5	3.1	22.6-28.8
Tilaknagar	5	4	4 - 6	19.4	6.8	10.7-29.3	20.0	8.5	15.8-24.1
Raja-ka-Tal	7	5	5 - 9	18.9	13.4	9.4-28.4	21.3	11.2	19.2-25.8
CPCB Standard	80			80			400		

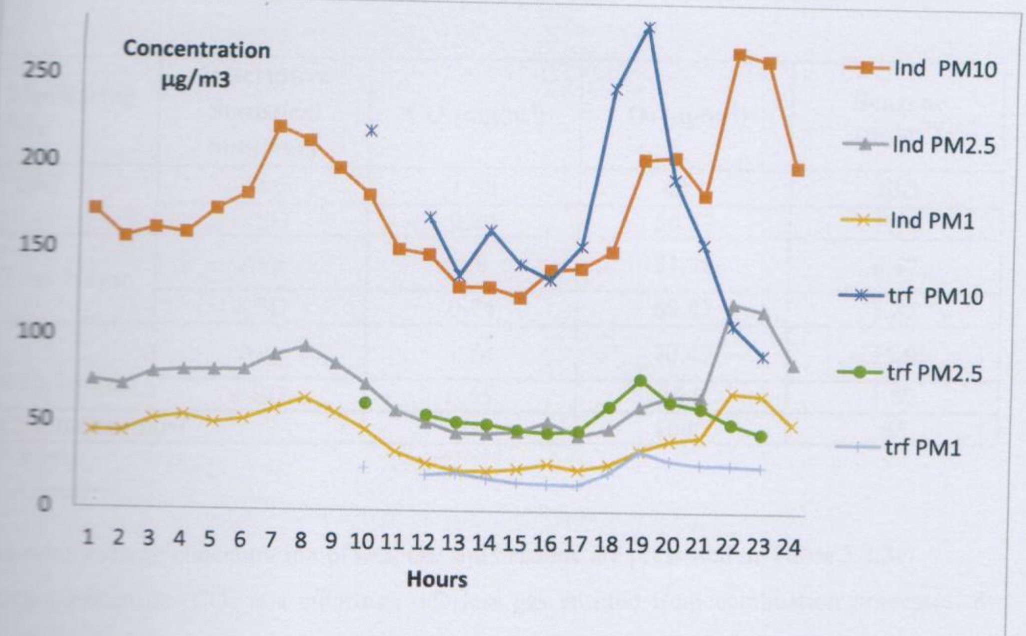


Fig. 3.2.4 Diurnal variation of PM_{10}, $PM_{2.5}$ and PM_1 at industrial location (Ind) and at traffic (trf) junction

At DIC, a mixed area, NO_2 were in the range of 17.9 -45.0 μg/m³ with mean value of 31.0 ± 10.1 μg/m³. Average concentrations of NO_2 was 19.4 (± 16.8 μg/m³) and ranged between 6.8 and 10.7 μg/m³ at Tilak Nagar while at Raja-ka-Tal, the NO_2 levels were 18.9 (± 13.4) μg/m³ and their levels were varied between 9.4 and 28.5 μg/m³.

Average concentrations of SO_2 at all the sites were much below the NAAQS regulatory limit (80 μg/m³) at all the sites. Average concentration of NH_3 at all the sites was also within the CPCB permissible limit of 400 μg/m³.

During the study period, temperature, relative humidity, wind speed were in the range of 24–39°C (mean 31.0°C), 16–87% (mean 45%), 0–3 km/h (mean 0.5 km/h) respectively in the study area. Wind direction dominated from westerly direction towards the station (as depicted in the windrose, Chapter 2) with 70% calm conditions. As compared to Tilak Nagar and Raja-ka-Tal, higher PM_{10}, $PM_{2.5}$ SO_2 and NO_2 levels were found at DIC. This site is located in downward direction to glass industry as well as it is also influenced by other ongoing activities.

Table 3.2.3c: Statistical Summary of Concentrations of CO, O_3 and Benzene

Monitoring Site	Descriptive Statistical Summary	CO (mg/m³)	O_3 (μg/m³)	Benzene (μg/m³)
DIC	Avg	1.58	62.6	20.3
	± SD	0.84	56.59	1.14
Tilak Nagar	Avg	1.9	51.38	8.47
	± SD	0.74	69.87	1.83
Raja ka Taal	Avg	1.54	70.49	15.0
	± SD	0.55	35.8	1.62
CPCB Standard		**2***	**100***	**5#**

* 8-hrly

\# Annual

Site-wise average concentration of CO, O_3, and benzene are presented in **Table 3.2.3c.** Carbon monoxide (CO) is a colorless, odorless gas emitted from combustion processes. 8-hourly average CO concentration were 1.58, 1.9, 1.54 μg/m³ at DIC, Tilak Nagar and Raja ki Taal respectively; well below the prescribed limit of CPCB.

Benzene is found in the air from emissions from burning coal and oil, gasoline service stations, and motor vehicle exhaust. 8-hourly average benzene concentration were 20.3, 8.47, 15.0 μg/m³ at DIC, Tilaknagar and Raja-ka-Taal respectively. Although, average benzene values are exceeding the CPCB standard of 5 µg/m^3 (annual average) in all three locations, maximum average concentration was found at DIC which represents a mixed area.

Ozone is formed by the chemical reaction between NO_x and VOCs emitted by cars, power plants, industrial boilers, refineries, chemical plants, and other sources in the presence of sunlight & heat. Average concentrations of O_3 were 62.6, 51.4, 70.5 µg/m^3 at DIC, Tilak nagar and Raja ki Tal respectively well below the prescribed limit of CPCB standard of 100 µg/m3.

3.3 Chemical Speciation of Particulate Matter

In order to check compliance of chemical species attached to PM in ambient air with regulatory standards and to assess the impact of various sources/processes on air quality, further characterization of PM_{10} was done. Different raw materials are used in glass industries; important are sand (SiO_2 + different minerals), soda ($NaHCO_3$), and limestone ($CaCO_3$) with specific additives (e.g. metal oxides, a list of additives is attached in Chapter IV) including recycled glass.

Iron (Fe), aluminum (Al), magnesium (Mg), potassium (K), calcium (Ca), silicon (Si) are the crustal elements and also present in the source along with the other elements namely arsenic, nickel, manganese and other metal oxides. Therefore, these crustal elements and other elements (Pb As, Ni) were characterized in PM_{10}. Samples were digested with concentrated nitric acid in a specialized microwave oven and filtrate was analyzed on ICP-OES for various elements.

3.3.1 Elements in Ambient Air

The concentration of elements in PM_{10} at all three sites are summarized in **Table 3.3.1.** It is observed that Pb content in PM_{10} was found to be similar at DIC and Tilak Nagar while it was comparatively lower at Raja ki Tal. The average concentration of Pb was found to be well below the CPCB standards of 1 µg/m^3 (24hr average). Arsenic (As) detected in PM_{10} at all the sites and levels were exceeding the CPCB standard of 6 ng/m^3 (annual average). The average concentration of Ni was exceeding the prescribed limit of 20 ng/m^3 (annual average) at DIC. Highest concentration of all the elements are found at DIC, a site located to downwind direction to the glass industry. Pb, Cd, As, Se, Ba, S are used more or in less amount in glass industry. The levels of these elements are higher at DIC followed by Tilkanagar.

Table 3.3.1: Concentration of elements in PM_{10} Samples µg/m3

		TILAK NAGAR		DIC OFFICE		RAJA Ka TAL		CPCB Standard
Sr. no.	ELEMENTS	AVG	± SD	AVG	± SD	AVG	± SD	
1	Co	Bdl	-	Bdl	-	0.046	8.0	
2	Cr	0.089	2.1	0.056	4.9	0.772	3.3	
3	Cu	0.025	4.3	0.007	0.9	0.003	5.1	
4	Fe	5.379	2.2	2.366	1.0	4.60	6.3	
5	Mn	0.116	3.0	0.085	2.7	0.010	4.4	
6	Ni	Bdl	-	0.039	4.9	Bdl		**0.02#**
7	Ti	15.206	4.8	5.824	2.2	0.480	1.0	
8	V	Bdl	-	0.021	4.6	0.025	1.2	
9	Mg	1.957	2.5	1.242	2.9	0.221	2.1	
10	Sr	0.033	1.5	0.016	6.3	0.004	5.0	
11	Ba	0.416	4.2	0.546	4.2	0.280	2.2	
12	Ca	6.456	2.8	3.297	2.0	0.416	4.4	
13	K	5.385	1.1	5.855	-	4.135	0.8	
14	Na	-	-	-	-	4.1	5.0	
15	Pb	0.70	3.0	0.717	4.9	0.198	2.7	**1***
16	Al	3.957	4.4	2.648	2.9	0.746	4.9	
17	Hg	0.006	0.8	0.010	1.5	0.027	2.2	
18	Zn	0.792	1.0	1.608	4.2	0.230	1.1	
19	Cd	2.527	2.7	2.797	2.8	0.020	1.1	
20	Si	10.251	4.9	6.839	9.1	1.276	3.0	
21	As	0.035	2.2	0.035	1.1	0.004	0.9	**0.006#**
22	Se *	0.702	4.3	1.089	2.7	0.055	1.2	
23	S *	5.058	2.1	4.719	4.4	2.157	3.6	

*24-hrly
Annual

*Non-metallic elements

3.3.2 Cations and Anions

For cations and anions, samples were sonicated in deiniosed water and filtered through 0.4 micron PTFE filter and then injected in Dionex Ion Chromatograph. CS-12 and AS-11 column followed by electrolytic suppression of background conductivity of the carrier solution were used for determining cations and anions in the samples.

Table 3.3.2: Concentration of Cations and Anions in PM_{10} Samples

		TILAK NAGAR		DIC OFFICE		RAJA KI TAAL	
Sr no		AVG	±SD	AVG	±SD	AVG	±SD
	Cations						
1	Na^+	1.16	5.4	7.71	4.3	3.47	2.3
2	K^+	0.36	5.5	3.95	3.6	1.07	3.3
3	Mg^{+2}	0.05	1.4	0.44	0.8	0.16	0.9
4	Ca^{+2}	1.71	4.5	9.72	5.2	5.12	2.0
5	NH_4^+	0.29	4.01	4.99	3.39	0.87	2.8
	Anions						
6	F^-	2.49	1.3	17.91	1.1	7.48	0.6
7	Cl^-	0.67	2.0	5.19	4.1	2.02	5.2
8	SO_4^{2-}	2.10	8.9	18.77	9.4	6.29	6.7
9	NO_3^-	1.44	2.9	13.26	1.6	4.32	1.7

Calcite Powder (CaCO3 (93-97%), MgO (1 -5%),+SiO2), Sodium Carbonate (Na_2CO_3), Sodium Tetra Borate Pentahydrate ($Na_2B_4O_7.5H_2O$) are used as raw material in glass industries. Ionic abundances of inorganic compounds followed the trends F^->SO4^{2-} >Ca^{2+}> NO3 $^-$ >Na^+> Cl^-

For cations and anions, samples were sonicated in deiniosed water and filtered through 0.4 micron PTFE filter and then injected in Dionex Ion Chromatograph. CS-12 and AS-11 column followed by electrolytic suppression of background conductivity of the carrier solution were used for determining cations and anions in the samples.

Table 3.3.2: Concentration of Cations and Anions in PM_{10} Samples

		TILAK NAGAR		DIC OFFICE		RAJA KI TAAL	
Sr no		**AVG**	**±SD**	**AVG**	**±SD**	**AVG**	**±SD**
	Cations						
1	Na^+	1.16	5.4	7.71	4.3	3.47	2.3
2	K^+	0.36	5.5	3.95	3.6	1.07	3.3
3	Mg^{+2}	0.05	1.4	0.44	0.8	0.16	0.9
4	Ca^{+2}	1.71	4.5	9.72	5.2	5.12	2.0
5	NH_4^+	0.29	4.01	4.99	3.39	0.87	2.8
	Anions						
6	F^-	2.49	1.3	17.91	1.1	7.48	0.6
7	Cl^-	0.67	2.0	5.19	4.1	2.02	5.2
8	SO_4^{2-}	2.10	8.9	18.77	9.4	6.29	6.7
9	NO_3^-	1.44	2.9	13.26	1.6	4.32	1.7

Calcite Powder ($CaCO_3$ (93-97%), MgO (1 -5%),+SiO_2), Sodium Carbonate (Na_2CO_3), Sodium Tetra Borate Pentahydrate ($Na_2B_4O_7.5H_2O$) are used as raw material in glass industries. Ionic abundances of inorganic compounds followed the trends $F^- > SO_4^{2-} > Ca^{2+} > NO_3^- > Na^+ > Cl^-$

$>K^+>NH4^+>Mg$ at Tilak Nagar (2.49,2.10,1.71,1.44,1.16,0.67,0.36,0.29 and 0.05 µg/m3) and Raja ki Taal (7.48,6.29,5.12,4.32,3.47,2.02,1.07,0.87 and 0.16 µg/m3)whereas at DIC the trend was as follows $SO4^{2-}$ $>F^->$ $NO3^-$ $>$ Ca^{2+} $>$ $Na^+>$ $Cl^->$ $NH4^+$ $>K^+>$ Mg+ (18.77,17.91,13.26,9.72,7.71,5.19,4.99,3.95 and 0.44 µg/m3). Respective average concentrations are given in brackets. Among all the sites, highest concentrations were observed at DIC followed by Raja-ka-Taal and then by Tilak nagar. The observed levels are as per the meteorological observations and varied among the sites as per the intensity of ongoing activities in the studied are as well as the influence of emissions of glass industry.

SO_2, NO_2, fluorides (F^-), and chlorides (Cl^-) are emitted from glass industries. Among all the ions higher concentration of F^-, sulphate and nitrate and calcium were observed at DIC. NO_3^- and $SO4^{2-}$ ions are generally found to be produced as secondary inorganic aerosol (SIA) during combustion and vehicular emissions. Among all the ions, $SO4^{2-}$ was the most abundant species at DIC while F^- levels were higher at DIC and Raja Ka Tal. Presence of F^- confirms the contribution of glass industry to the surrounding area.

Among the three sites, average concentration of K^+, which is considered as a biomass tracer was found to be slightly higher at DIC site followed by Raja- ki-Tal and then by Tilaknagar which may be due to biomass/agricultural burning in the surrounding area. At all the sites Mg, was the lowest element.

3.3.3 Carbonaceous matter and Polycyclic Aromatic Hydrocarbon (BaP)

Elemental carbon (EC) and organic carbon (OC) were analyzed using DRI Model 2001 Thermal and Optical Carbon Analyzer, based on the preferential oxidation of OC and EC compounds at different temperatures with the IMPROVE thermal/optical reflectance (TOR) protocol. For PAHs, samples were sonicated in cyclohexane and filtered through G-4 sinter crucible. The filtrate was concentrated in rotary evaporator and then diluted in DCM solution. The sample was then analyzed by Gas Chromatograph-Mass Spectrometry.

Table 3.3.3: Concentrations of OC, EC (µg/m3) and B(a)P (ng/m3) in PM_{10} Samples

Sr no	Parameters	Tilaknagar		DIC Office		Raja KI Tal	
		AVG	±SD	AVG	±SD	AVG	±SD
1	OC	22.88	15.3	70	40.0	26.56	12.5
2	EC	6.87	10.5	9.46	6.3	10.71	6.0

3	BaP	2.19	2.8	7.4	1.6	6.0	8.0

Carbonaceous matter (organic carbon, (OC) and elemental carbon (EC) contributes significantly to PM. Out of these carbons, EC is a primary pollutant and emits directly during incomplete combustion of carbon based materials and fuels processes. It is the dominant light absorbing species in the atmosphere. Whereas, OC can be directly released as primary organic aerosol (POA) into the atmosphere as products of fossil fuel combustion or biomass burning or produced via secondary gas-to particle conversion of volatile organic compounds (VOCs) to secondary organic aerosol (SOA).

At DIC, highest concentration of OC (70 μg/m3) was found than that of Raja Ka Taal (26.56 μg/m3) and Tilaknagar (22.88 μg/m3) whereas comparatively higher EC were observed at DIC (9.46 μg/m3) and Raja Ka Taal (10.71 μg/m3). Presence of OC and EC specifies the presence of sources such as diesel generator, diesel and petrol driven vehicular emissions and biomass agricultural burning.

PAHs are a class of organic compounds that are formed during incomplete combustion or pyrolysis or pyro-synthesis of organic materials containing carbon and hydrogen. High levels of B(a)P (one of the carcinogenic PAHs) could be due to incomplete combustion of fossil fuel. The average concentration of B(a)P is above the CPCB standard of 1 ng/m^3 (annual average) at all the three locations.

3.4 Comparison of present air pollution level in Firozabad with that of 1993

Data in 1993 and 2015 are compared and results are shown in Fig 3.2.2 and Fig.3.2.3 for PM and SO_2 and NO_2 respectively.

Generally, suspended particulate matter (SPM) refers to particles in the air of all sizes. SPM is a complex mixture of organic substances, present in the atmosphere both as solid particles and liquid droplets. They include fumes, smoke, dust and aerosols. Health impacts of PM vary depending on the size and the concentration of particles. For regulatory purposes and for estimating health impacts, PM is measured as PM_{10} and $PM_{2.5}$.

- PM_{10} refers to particles with a diameter less than 10 microns. These are commonly called coarse particles - they contain dust from roads and industries as well as particles formed under combustion. Depending on their size, coarse particles can lodge in the trachea (upper throat) or in the bronchi.

- $PM_{2.5}$ refers to particles with a diameter of less than 2.5 microns. These are usually called fine particles and contain secondary aerosols, combustion particles and re-condensed organic metallic vapour, and acid components. Fine particles can reach all the way down to the alveoli in the lungs.

It is therefore not possible to compare SPM, PM_{10} and $PM_{2.5}$ due to their nature of origin and composition. However, SPM data collected from Regional Office, U.P.PCB, Firozabad are provided to compare with that of 1993.

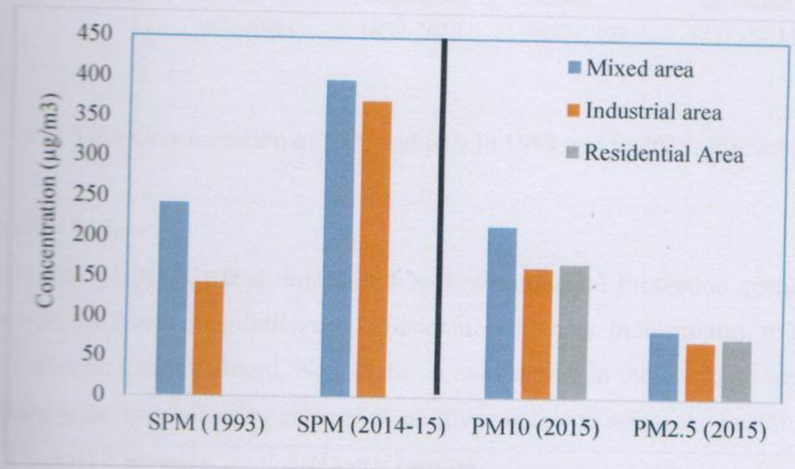


Fig 3.2.5 Concentration of SPM in 1993 and in 2014-15, PM10, and $PM_{2.5}$ in 2015: Firozabad (SPM of 2014-15 were taken from Regional Office, U.P. PCB, Firozabad)

Levels of SO_2 are decreased drastically by two times while levels of NO_2 are increased by 1.4 to 2.6 times when compared with the levels of SO_2 and NO_2 in 1993.

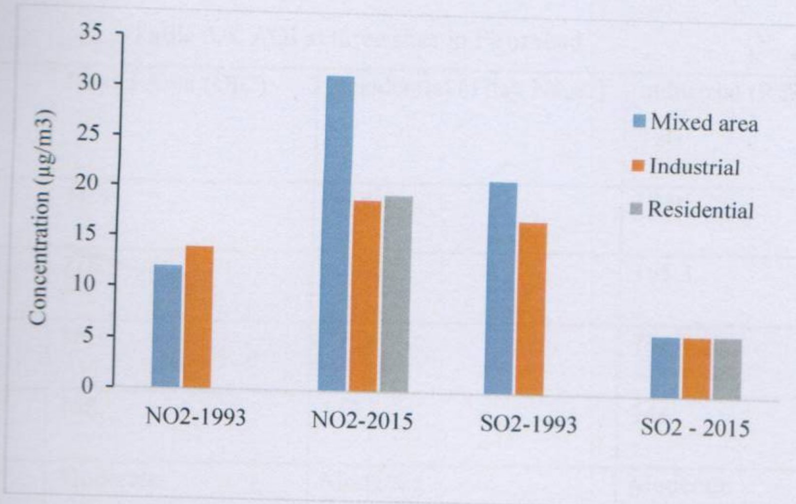


Fig 3.2.6 Concentration of NO_2 and SO_2 in 1993 and in 2015: Firozabad

3.5 Air Quality Index

Air Quality Index (AQI) is a tool, introduced by Environmental Protection agency (EPA) in USA to measure the levels of pollution due to major air pollutants. In this report, AQI developed by Central Pollution Control Board, New Delhi is used to obtain the combine scenario of air pollution in the area. The following categories are given below to assess the health impact.

AQI	AQI Category	Health Impact
0-50	Good	Minimal impact
51-100	Satisfactory	Minor breathing discomfort to sensitive people
101-200	Moderately Polluted	Breathing discomfort to the people with lung, heart disease, children and older adults
201-300	Poor	Breathing discomfort to people on prolonged exposure
301-400	Very Poor	Respiratory illness to the people on prolonged exposure
401-500	Severe	Respiratory effects even on healthy people

The details of the index are given in **http://www.cpcb.nic.in/AQI_new.php**. Three pollutants NO_2, PM_{10} and $PM_{2.5}$ are considered to compute AQI. Table 3.5 gives the AQI for three sites.

Table 3.5. AQI at three sites in Firozabad

	Mixed Area (DIC)	Residential (Tilak Nagar)	Industrial (Raja ka Tal)
NO_2	31.3	19.4	18.9
PM_{10}	216.3	170.3	165.3
$PM_{2.5}$	86.3	77.2	73
AQI	188	157	144
AQI Category	Moderate	Moderate	Moderate

It can be seen from Table 3.5 that AQI falls in the category "Moderate" which suggests that there may be a moderate health concern for a small number of people who are sensitive to dust pollution (as per CPCB).

3.6 Air Quality and Census (2011) Data of Firozabad and Agra

Present air quality status of Firozabad and Agra (for last 5 months) are shown in the following tables (3.6.1 and 3.6.2) which have been collected from UP Pollution Control Board, Lucknow. Values of SO_2 and NO_2 are well below the standard limit (CPCB) for all locations in both cities whereas PM_{10} value exceeded in all monitoring locations for both cities.

Table 3.6.1 Firozabad Air Quality (ref: UP PCB)

Location	Oct-15	Nov-15	Dec-15	Jan-16	Feb-16
		SO_2			
CDGL S.N. marg	10	10	11	10	9
Tilak nagar	9	11	10	9	9
Raja ki Taal	10	10	10	9	10
Average	**10**	**10**	**10**	**9**	**9**
		NO_2			
CDGL S.N. marg	32	34	37	38	38
Tilak nagar	31	34	38	37	39
Raja ki Taal	33	33	35	39	39
Average	**32**	**34**	**37**	**38**	**38**
		PM_{10}			

	Agra-2011			Firozabad-2011		
Total population	Total	Rural	Urban	Total	Rural	Urban
Persons	4,418,797	2,394,602	2,024,195	2,498,156	1,664,987	833,169
Males	2,364,953	1,285,184	1,079,769	1,332,046	891,872	440,174
Females	2,053,844	1,109,418	944,426	1,166,110	773,115	392,995
Area in Sq. Km.	4,041.00	3,793.00	248	2,407.00	2,344.00	63
Density of Population	1,094	631	8,162	1,038	710	13,225

CDGL S.N. marg	202	254	277	300	310
Tilak nagar	211	284	287	303	297
Raja ki Taal	255	268	273	298	302
Average	**223**	**269**	**279**	**300**	**303**

Table 3.6.2 Agra Air Quality (ref: UP PCB)

Location	Oct-15	Nov-15	Dec-15	Jan-16	Feb-16
		SO_2			
Bodla	6.1	6.9	6.87	7.02	9
Nunhai	9.3	9.8	11.34	10.23	11
Ave.	**8**	**8**	**9**	**9**	**10**
		NO_2			
Bodla	12.7	10.8	16.5	14.2	14
Nunhai	15.1	15.8	19.75	18.8	18
Ave.	**14**	**13**	**18**	**17**	**16**
		PM_{10}			
Bodla	233.3	268.1	214	263.8	198
Nunhai	260.3	403	280.2	282.2	274
Ave.	**247**	**336**	**247**	**273**	**236**

Some comparative details (ref: census 2011 Govt. Of India) about numbers of towns, villages, households and population are given in table 3.6.3 and 3.6.4 for Agra and Firozabad.

Table 3.6.3 Agra and Firozabad census (ref: census 2011 Govt. Of India)

Table 3.6.4 Agra and Firozabad population comparison (ref: census 2011 Govt. Of India)

	Agra-2011	Firozabad-2011
Sub-Districts	6	4
Towns	27	9
Statutory Towns	14	6
Census Towns	13	3
Villages	929	807
Normal Households	703,637	410,548
Institutional Households	4,509	3,010
Houseless	2,420	708

Annexure 1

Table 3.6.5 National Ambient Air Quality Standards, as of 2009

Pollutant	Time Weighted Average	Concentration in Ambient Air: Industrial, Residential, Rural and Other Area	Concentration in Ambient Air: Ecologically Sensitive Area (notified by Central Government)	Methods of Measurement
SO_2, µg/m^3	Annual*	50	20	• Improved West and Gaeke • Ultraviolet fluorescence
	24 hours**	80	80	
NO_2, µg/m^3	Annual*	40	30	

	24 hours**	80	80	• Modified Jacob & Hochheiser (Na-Arsenite) • Chemiluminescence
PM_{10}, µg/m^3	Annual*	60	60	• Gravimetric • TOEM • Beta attenuation
	24 hours**	100	100	
$PM_{2.5}$, µg/m^3	Annual*	40	40	• Gravimetric • TOEM • Beta attenuation
	24 hours**	60	60	
O_3, µg/m^3	8 hours**	100	100	• UV photometric • Chemiluminescence • Chemical Method
	1 hour**	180	180	
Lead (Pb), µg/m^3	Annual*	0.50	0.50	• AAS/ICP method after sampling on EMP 2000 or equivalent filter paper • ED-XRF using Teflon filter
	24 hours**	1	1	
CO, mg/m^3	8 hours**	2	2	• Non Dispersive Infra Red (NDIR) spectrosopy
	1 hour**	4	4	
Ammonia (NH_3) µg/m^3	Annual*	100	100	• Chemiluminescence • Indophenol blue method
	24 hours**	400	400	
Benzene µg/m^3	Annual*	5	5	• Gas chromatography based on continuous analyzer • Adsorption and Desorption followed by GC analysis
Benzopyrene (BaP) - particulate phase only, ng/m^3	Annual*	1	1	• Solvent extraction followed by HPLC/GC analysis
Arsenic (As), ng/m^3	Annual*	6	6	• AAS/ICP method after sampling on EMP 2000 or equivalent filter paper
Nickel (Ni), ng/m^3	Annual*	20	20	• AAS/ICP method after sampling on EMP 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 intervals.
** 24 hourly or 8 hourly or 1 hourly monitored values, as applicable, shall be compiled with 98% of the time in a year. 2% of the time, theymay exceed the limits but not on two consecutive days of monitoring.
Note – Whenever and wherever monitoring results on two consecutive days of monitoring exceed the limits specified above for the respective category, it shall be considered adequate reason to institute regular or continuous monitoring and further investigation.