

“Assessment of Ambient Air Quality of Lucknow City”

A Dissertation submitted for the partial fulfillment of the requirements

for the award of M.Sc. degree in

ENVIRONMENTAL SCIENCE

Submitted By

PANKAJ VERMA

Roll No. 2101052007

Enrollment No. 2100100723

Department of Environmental Science



Integral University, Lucknow.

Internal Supervisor:

DR. RAHILA RAHMAN KHAN

(Assistant Professor) Department of

Environmental science, Integral

University, Lucknow Uttar

Pradesh



External Supervisor:

Shree Ram Gopal (Chief UPPCB) Lucknow U.P INDIA2023

ACKNOWLEDGEMENT

Firstly, I bow my head with utmost reverence before the Almighty whose eternal blessing has enabled me to accomplish this noble effort.

I express my heartfelt thanks to Dr. M.A.Khalid (Professor and Head of Department), of Environmental Science, Integral University.

I have much to thank my guide Dr. Rahila Rahman Khan (Assistant Professor Environmental Science, Integral University) for not only providing me with a novel topic but also for taking enormous pains to helping me in the qualitative completion of the mastered work. His profound understanding of the subject and igneous insight helped every stage.

I am privileged to work under the Co-supervisor of Shree Ram Gopal (Chief of UPPCB) Lucknow. It was my opportunity to be guided by a person of calibre, whose blessings brings best in every one of my endeavours. His keen interest, constructive discussions, clear understanding and great support provided me an excellent atmosphere for completing this study. Working under him has been a great experience and I shall forever treasure this association.

I pay my sincere regards to Dr. Shadma (scientist UPPCB) Lucknow for his encouragement, inspiration, parental affection, keen interest and advice throughout my work.

I owe my unpayable debt and special thanks to all my senior lab mates, Miss. Kajal (Lab Assistant), Vishal Kumar (Librarian) who helped me at several stages during the work. The encouragement rendered by them has helped me to overcome several hurdles to complete this dissertation.

Nothing can be achieved without the support of family members. I gratefully acknowledge the constant support, love care and great understanding of my father Mr. J.P. Verma, my mother Smt. Parwati Devi.

Finally I am thanking for providing me this opportunity to undertake postgraduate studies in this institute.....

**Candidate
Panakj Verma**

DECLARATION

This is certify that project entitled “**Assessment of Ambient Air quality of Lucknow City** ” is my work that it has not been submitted for any degree or examination in any other university, complete references. And that all the sources I have used or quoted have been indicated and acknowledged by complete references.

The work was done under the guidance of Ram Gopal (Chief of UPPCB) Lucknow.

Pankaj verma
M.Sc. 2nd year
Integral University
Lucknow,UP,INDIA

TABLE OF CONTENTS

S. No.	Chapter	Page No.
1	Introduction	1-3
2	Review of Literature	4-8
4	Material & Method	9-43
5	Result & Discussion	44-58
6	Conclusion	59-60
7	Recommendation	61
8	Reference	62-63

INTRODUCTION

NATIONAL AMBIENT AIR QUALITY STANDARDS (2009)

Pollutants	Time Weighted Average	Concentration in Ambient Air		Methods of Measurement
		Industrial, Residential, Rural and other Areas	Ecologically Sensitive Area (Notified by Central Government)	
Sulphur Dioxide (SO ₂), µg/m ³	Annual * 24 Hours **	50 80	20 80	-Improved West and Gaeke Method -Ultraviolet Fluorescence
Nitrogen Dioxide(NO ₂), µg/m ³	Annual * 24 Hours **	40 80	30 80	-Jacob & Hochheiser modified(NaOH-NaAsO ₂) Method -Gas Phase Chemiluminescence
Particulate Matter (Size less than 10µm)or PM ₁₀ , µg/m ³	Annual * 24 Hours **	60 100	60 100	-Gravimetric -TEOM -Beta attenuation
Particulate Matter (Size less than 2.5µm)or PM _{2.5} , µg/m ³	Annual * 24 Hours **	40 60	40 60	-Gravimetric -TEOM -Beta attenuation
Ozone (O ₃)µg/m ³	8 Hours * 1 Hour **	100 180	100 180	-UV Photometric -Chemiluminescence -Chemical Method
Lead (Pb)µg/m ³	Annual * 24 Hours **	0.50 1.0	0.50 1.0	-AAS/ICP Method after sampling onEPM 2000 or equivalent filter paper -ED-XRF using Teflon filter
Carbon Monoxide(CO), mg/m ³	8 Hours ** 1 Hour **	02 04	02 04	-Non dispersive Infrared (NDIR) Spectroscopy
Ammonia (NH ₃),µg/m ³	Annual * 24 Hours **	100 400	100 400	-Chemiluminescence -Indophenol blue method
Benzene (C ₆ H ₆),µg/m ³	Annual *	05	05	-Gas Chromatography (GC) based continuous analyzer -Adsorption and desorption followed by GC analysis
Benzo(a)Pyrene (BaP) Particulate phase only, ng/m ³	Annual *	01	01	-Solvent extraction followed byHPLC/GC analysis
Arsenic (As), ng/m ³	Annual *	06	06	-AAS/ICP Method after sampling on EPM 2000 or equivalent filter paper
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 intervals.

** 24 hourly or 8 hourly or 1 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.

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 investigations.

Air quality of Lucknow city

Lucknow is the capital city of Uttar Pradesh, a state located in the northern region of India. It has some three and a half million people living there, making it extremely dense population wise. In terms of the levels of pollution in the city, they rank amongst some of the worst in the world, with year-round PM_{2.5} readings that have severe health consequences for its citizens to breathe.

In 2019, the readings of PM_{2.5} (particulate matter of 2.5 micrometres or less in diameter) came in at 90.3 $\mu\text{g}/\text{m}^3$, putting it in the ‘unhealthy’ bracket, which requires a PM_{2.5} reading of anywhere between 55.5 to 150.4 $\mu\text{g}/\text{m}^3$ to be classified as unhealthy. This yearly reading would make the air extremely unsafe for every portion of the population to breathe, with young children and the elderly or sick being particularly at risk.

This reading of 90.3 $\mu\text{g}/\text{m}^3$ put it in 7th place out of all the cities ranked in India, and 11th place out of all cities ranked worldwide in 2019. With these statistics it is apparent that the air quality in Lucknow is not only unhealthy, but outright dangerous, with some months of the year skyrocketing even higher into the ‘very unhealthy’ bracket. Observing the data from the last few years, Lucknow came in over 2017 with a PM_{2.5} average reading of 119.2 $\mu\text{g}/\text{m}^3$, and then in 2018 with 115.7 $\mu\text{g}/\text{m}^3$. When compared to the most recent yearly average of 2019, which came in at 90.3 $\mu\text{g}/\text{m}^3$, it goes to show that Lucknow has made quite significant improvements in terms of its overall air quality.

Air quality (AQ) is a global concern for human health management. Therefore, air quality monitoring (AQM) and its management is a must-needed activity for the current world environment. A systematic review of various sensors and systems for AQ management may strengthen our understanding of the monitoring and management of AQ. Thus, the current review presents details on sensors/systems available for AQ assessment, monitoring, and management. First, we had gone through the published literature based on special keywords including AQM, Particulate Matter (PM), Carbon Mono-oxide (CO), Sulfur di-Oxide (SO₂), and Nitrogen di-Oxide (NO₂) among others, and identified the current scenario of research in AQ management. We discussed various sensors/systems available for the AQ management based on self-conceptualized five major categories including, ground-based AQS (wet chemistry) systems, and ground-based digital sensors systems, aerial sensors systems, satellite-based sensors systems, and integrated systems. The prospects in the field of AQ assessment and management (AQA&M) were then discussed in detail. We concluded that the AQA&M can be better achieved by coupling new technologies like ground-based smart sensors, satellite remote sensing sensors, Geospatial technologies, and computational technologies like machine learning, Artificial intelligence, and Internet of Things (IoT). The current work may lead to a junction of information for connecting these sensors/systems, which is expected to be beneficial in future AQ research and management.

Why we monitor air quality

- To find out where air quality needs to be improved.
- To keep communities informed about their local air quality.
- To determine whether efforts to improve air quality are working.
- To understand how air pollution may effect human health and the environment.

Ambient Air Quality

- The quality of outdoor air in our surrounding environment. It is typically measured near ground level, away from direct sources of pollution.
- Ambient Air monitoring is an integral part of an effective air quality management System. Reasons to collect data include to: Assess the extent of pollution.
- Provide air pollution data to general public in a timely manner.
- Support the implementation of air quality goals or standard.
- Evaluate the effectiveness of emissions control strategies.
- Provide information on air quality trends.
- Provide data for the evaluation of air quality models.
- Support research (e.g. long term studies of the health effects of air pollution).
- There are different method to measure any given pollutant. A developer of a monitoring strategy should examine the option to determine which methods are most appropriate, taking in to account the main uses of data, initial investment cost for equipment, operating costs, reliability of system and ease of operation.

Particulate matter

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.

Particle pollution includes:

PM₁₀: inhalable particles, with diameters that are generally 10 micrometers and smaller; and
PM_{2.5}: fine inhalable particles, with diameters that are generally 2.5 micrometers and smaller. Some particles are directly emitted into the air (primary particulate matter). They come from a variety of sources such as cars, trucks, buses, factories, construction sites, tilled fields, unpaved roads, stone crushing, and burning of wood.

Other particles may be formed in the air from the chemical change of gases (Secondary particles). They are indirectly formed when gases from burning fuels react with sunlight and water vapors. These can result from fuel combustion in motor vehicles, at power plants, and in other industrial processes.

Review of Literature

The PM₁₀ concentration (µg/m³) in Lucknow city at 4 locations in three different seasons ranged between 148.6–210.8 (avg. 187.2 ± 17.1) during summer, 111.8– 187.6 (avg. 155.7 ± 22.7) during monsoon and 199.3– 308.8 (avg. 269.3 ± 42.9) during winter while PM_{2.5} ranged between 32.4–67.2 (avg. 45.6 ± 10.9), 25.6–68.9 (avg. 39.8 ± 4.6) and 99.3–299.3 (avg. 212.4 ± 55.0) during respective seasons. The mass fraction ratio of PM_{2.5} ranged between 0.22–0.92 (avg. 0.42 ± 0.26) and was significantly high during winter season indicating their composition. (P. Pandey et.al. 2011). The average concentration of PM₁₀ during winters of 2002, 2003 and 2004 was 196.5, 266.8 and 166.3 µg/m³ in residential, 258.2, 321.7, 211.2 µg/m³ in commercial and 205.0, 231.5, 198.5 µg/m³ in industrial area respectively, were above their respective NAAQS of 100 µg/m³ for residential/ commercial, rural and other areas and 150 µg/m³ for industrial areas. The Pb concentration in this study ranged 0.07-0.89 µg/m³. Introduction of CNG buses for public transport in place of diesel-operated three wheelers on the trunk route resulted in lower PM₁₀ levels in 2004 (G. C Kisku et.al. 2013).

Particulate fractions viz.; PM_{2.5}, PM₁₀ and SPM were reported to be exceeded the National Ambient Air Quality Standards (NAAQS) limits in most of the studies but oxides of sulphur and nitrogen (SO₂ and NO_x) were within the limit of 80 µg/m³. Lack of dispersion of pollutants in winter season was reported to be the main reason for highest air pollution during this season and minimum in monsoon due to washout by rains. Commercial areas with high traffic volume recorded higher air pollution levels than residential and industrial areas with low traffic density. Vehicular traffic was identified the major source of air pollution in the city. Air pollution level at control site (village or low traffic density area) was lower than other urban sites. Particulates and associated toxic chemicals (metals and PAHs) and gaseous pollutants have found to be toxic to human and plants in Lucknow (A.K. Verma et.al. 2015).

In a study conducted at four locations of the city during 2007–09, the average value of PM₁₀ and PM_{2.5} was 168.1 (1.7 times) and 87.3 (1.5 times) µg/m³ higher than their respective NAAQS limits of 100 and 60 µg/m³. Amongst the metals associated with PM₁₀, maximum Fe and minimum Cd was observed. Concentration of Pb, 40.6 was less than 1000 ng/m³, while Ni, 35.1 exceeded 20 ng/m³ limits prescribed by NAAQS-2009.

The maximum values of metals were observed during winter. The average level of benzo(a)pyrene (51.96ng/m³) was about 50 times higher than the standard value of 1 ng/m³ (NAAQS-2009, India: annual average).

Author suggested that the higher prevalence of diseases viz.; asthma, tuberculosis, pneumoconiosis, chronic bronchitis and lung cancer among Lucknow population can be linked to the high concentration of fine particulates, toxic metals and PAHs found in urban atmosphere (D. Patel et. al. 2013).

According to the UPPCB (UTTAR PRADESH POLLUTION CONTROL BOARD) analysis of air quality parameters of different locations such as residential, commercial, for industrial areas Lucknow in year 2018.

In a study at ten locations during May, 2006 in urban area of Lucknow city and one nearby village (control), the values of PM₁₀ and SPM were found to be 168.2 and 374.5, 180.2 and 399.5, 141.4 and 327.8, 73.1 and 196.3 µg/m³ in residential, commercial, industrial and control village respectively. The concentration of SO₂ and NO_x in this study ranged from 11.7- 32.4

and 14.7-46.0 µg/m³. The mean concentration of air pollutants (RSPM, SPM, SO₂ and NO_x) found in the increasing order of village area (control).

Air pollution has emerged as a major challenge, particularly in urban areas. The problem becomes more complex due to the multiplicity and complexity of the air polluting source mix (e.g., industries, automobiles, generators, domestic fuel burning, road side dusts, construction activities, etc.)

. A human need air for respiration. An adult at rest breathes 16 respirations per minute-approximately 5 m³ /h (lungs volume 4-6 L), with harder work the rate is 3-6 times more (15-30 m³ /h). Poor air can have adverse impact on our quality of life and can damage the fabric of building and sensitive flora and fauna. Air pollution is the accumulation of hazardous substances into the atmosphere that danger human life and other living matter

. Outdoor PM air pollution is estimated to be responsible for about 3% of adult cardiopulmonary disease mortality, about 5% of trachea, bronchus and lung cancer mortality, and about 1% of mortality in children from acute respiratory infection in urban areas worldwide. This amounts to about 0.80 million (1.2%) premature deaths and 6.4 million (0.5%) lost life years.

The World Health Organization reports that in 2012 around 7 million people died - one in eight of total global deaths – as a result of air pollution exposure confirming that air pollution is now the world's largest single environmental health risk. Reducing air pollution could save millions of lives.

High PM₁₀ level in air may cause chronic and acute effects on human health, particularly the pulmonary function, as they can penetrate deep into the lungs and cause respiratory problems. Association with high levels of NO₂ etc. may further exaggerate such effect. High concentration of PM₁₀, sulfate and SO₂ would cause respiratory mortality in several situations.

Air quality within a region is affected by emission quantities and meteorological conditions. Good air quality is essential to human health, plants and animals, buildings and to the environment as well. Poor air quality adversely impacts our quality of life and can damage the fabric of building and sensitive flora and fauna. Ambient air monitoring stations measure air pollutant concentrations which not only determine existing air quality, but also help in evaluation of the effectiveness of air pollution control program and to identify areas in need of restoration and their prioritization. Air quality index (AQI) is designed to inform the public about the air quality in their surroundings.

As per report of WHO, 2014 the annual concentration of PM₁₀ was 219 µg/m³•

As per December, 2015 AQI of Lucknow was 489. The AQI between 401 and 500 is the severe call for the human health hazard. There is a high fluctuation rate in PM_{2.5}. According to the study, it revealed that the fluctuation of the PM depends upon the wind speed and humidity of the area. If the wind speed is less than 0.3 metre/second, it leads to concentration of particulate matter. Similarly, if humidity is high, particulate matter becomes heavy and remains suspended in the air thus causing pollution. As per the record of December 2015 in Talkatora station PM_{2.5} recorded alarmingly at high levels on the intervening night of 9th December, 2015 Wednesday and 10th December, 2015 Thursday

. The highest value was 15,080 microgram per cubic metre recorded at 2.30 am on Thursday. At 11.30 pm Wednesday, PM_{2.5} was recorded to be at 12,641 microgram per cubic metre. The

national ambient air quality standard for PM_{2.5} is 60 microgram per cubic metre and for PM₁₀ is 100 microgram per cubic metre.

According to USEPA (1999) Environmental Protection Agency (EPA) developed a uniform AQI in 1976 and primarily it was known as pollutant standard index, for the use of state and local agencies to assess urban air quality in USA. AQI may be defined as a single number for reporting the air quality with respect to its effect on human health. In most elaborate form it combines many air pollutant concentrations in some mathematical expression to arrive at a single number for air quality.

Air Pollution is now one of the most common occurring factor resulting into threatening to human health at great extent.

Air quality of Lucknow according to analysis of last nine years air quality data shows a more or less stable trend for SO₂ and a declining trend for NO₂, both lying within the NAAQS. For PM₁₀ increasing trend is seen which exceeds NAAQS (As per CPCB, 2012 report).

The ambient air quality studies of Lucknow reported in literature since the last many years have been summarized in this section. The researchers have studied ambient air pollution status and correlated it with environmental, human and plants health impacts. Survey at seven locations in residential, commercial and industrial areas of Lucknow during 1999-2000, showed that particulate concentration and their metallic content tend to fluctuate with the change in meteorological conditions. In this study levels of PM₁₀ was 230.9, 216.5, 261.5, 241.1 µg/m³ during winter, summer, pre and post monsoon respectively and the corresponding values for SPM were 565.4, 522.3, 918.4 and 551.9 µg/m³ respectively. All the value were higher than the prescribed NAAQS. Particulate fraction PM₁₀ assessed for heavy metals showed the presence of Cd, Cr, Cu, Fe, Mn, Ni, Pb and Zn in all the seasons. The results of the study indicate marked variations in the metal contents from different locations and differ significantly in different seasons. As per the authors opinion the higher particulates can be attributed to the greater density of small diesel driven vehicles plying through routes nearby sampling locations (A.Pradhan et.al. 2004).

Air pollution status at twelve sites (close to road crossings) in Trans-Gomti area (approximately half on one side of river dividing the city) of Lucknow was studied in moderate traffic hours (11.00 AM-1.00 PM) during 2000- 01, which is high traffic density areas. The observed average PM₁₀ in this study 499.4 µg/m³ was more than the NAAQS permissible limit (100 µg/m³).

The highest PM₁₀ level (995 µg/m³) was recorded at the busiest crossing with maximum traffic density (6723 vehicle/h) and least (150 µg/m³) at low traffic density crossing with minimum traffic load (52 vehicle/h). Gaseous pollutant (SO₂ and NO₂) levels were also recorded maximum (41.92 and 38.24 µg/m³) and minimum (SO₂-ND, NO₂-4.29 µg/m³) at the respective locations. The levels of all automobile pollutants showed a trend of positive correlation with the traffic density. The Air Quality Index (9.89) at low traffic density site which is also under thick forest cover is of very clean category and that of busiest crossing (68.42) near to the value of polluted category (75-100). This investigation revealed that environment of the Trans Gomti area is mainly contaminated with PM₁₀ and suggested to ban diesel driven vehicles in the city areas to bring down the PM₁₀ level within the permissible limit (A.Verma et.al.2003) 541.7 µg/m³ was higher than the NAAQS limits, while SO₂ (23.06-36.5 µg/m³) and NO_x (26.54-43.0 µg/m³) was less than the standards. (Tiwari et. al 2014) The

concentration of PM₁₀ at 10 locations in city was recorded in the range of 107.6-237.8 µg/m³ in summer (May, 2005) in Lucknow. It was 146.9 and 178.4 µg/m³ in residential and commercial areas where as 107.6 µg/m³ in one industrial area. The relative difference (%) of PM₁₀ with NAAQS i.e. the expedience factor ranged from 0.7 in industrial to 2.4 in commercial area. Author also reported that the mean concentration of Fe (1242.10 ng/m³) was maximum and Cd (6.36 ng/m³) minimum in the city. The concentration of PM₁₀ in air was found higher almost double than NAAQS. For high concentration of PM₁₀ in air trace metals Fe, Mn and Mg were found responsible. The adverse health effects of PM₁₀ related to Fe, Mn and Mg may be the reason for frequent hospital visitors. Author commented that the considerable abatement at root levels in the sources of these metals may reduce the concentration of PM₁₀ and thus the air quality as well as the health of the city dwellers will certainly improve (K.Sharma et.al. 2006).

OBJECTIVE

1. To Assess the SO₂ & NO₂ in selected location Gomti Nagar ,Talkatora, Aliganj of Lucknow City in The month of March & April 2023.
2. To Assess the PM_{2.5}, PM₁₀ in selected location Gomti Nagar ,Talkatora, Aliganj of Lucknow City in The month of March & April 2023.
3. To compare the selected pollutant data with previous year data. .

Material & Method

Guidelines for Sampling and Measurement of notified Ambient Air Quality Parameters (NAAQS 2009)

Under the provisions of the Air (Prevention & Control of Pollution) Act, 1981, the CPCB has notified fourth version of National Ambient Air Quality Standards (NAAQS) in 2009. This revised national standard aims to provide uniform air quality for all, irrespective of land use pattern, across the country. There are 12 identified health based parameters, which are to measure at the national level and with a view to have data comparison, need for uniform guidelines for monitoring, sampling, analyses, sample flow chart, data sheet based on standard method has been felt.

The methods prescribed in the notification for respective parameters are the combination of physical method, wet-chemical method and continuous on-line method. Therefore, to meet the NAAQS requirement, a combination of both manual and continuous method is invariably required at each monitoring location, besides good laboratory set up and infrastructure.

In addition to the above, an in house exercise for applicability of all prescribed / recommended analytical methods was also felt necessary. After review and demonstration in the Central Laboratory, Delhi, guidelines are being prepared and documented, as under:

Volume –I: Guidelines for manual sampling and analyses (along with sampleflow chart and data sheets)

Volume-II: Guidelines for continuous sampling and real time analyses

Study Area: Lucknow City

- Gomti Nagar
- Aliganj
- Talkatora

Guidelines for sampling and analysis of Sulphur dioxide in ambient air (Improved West and Gaeke method)

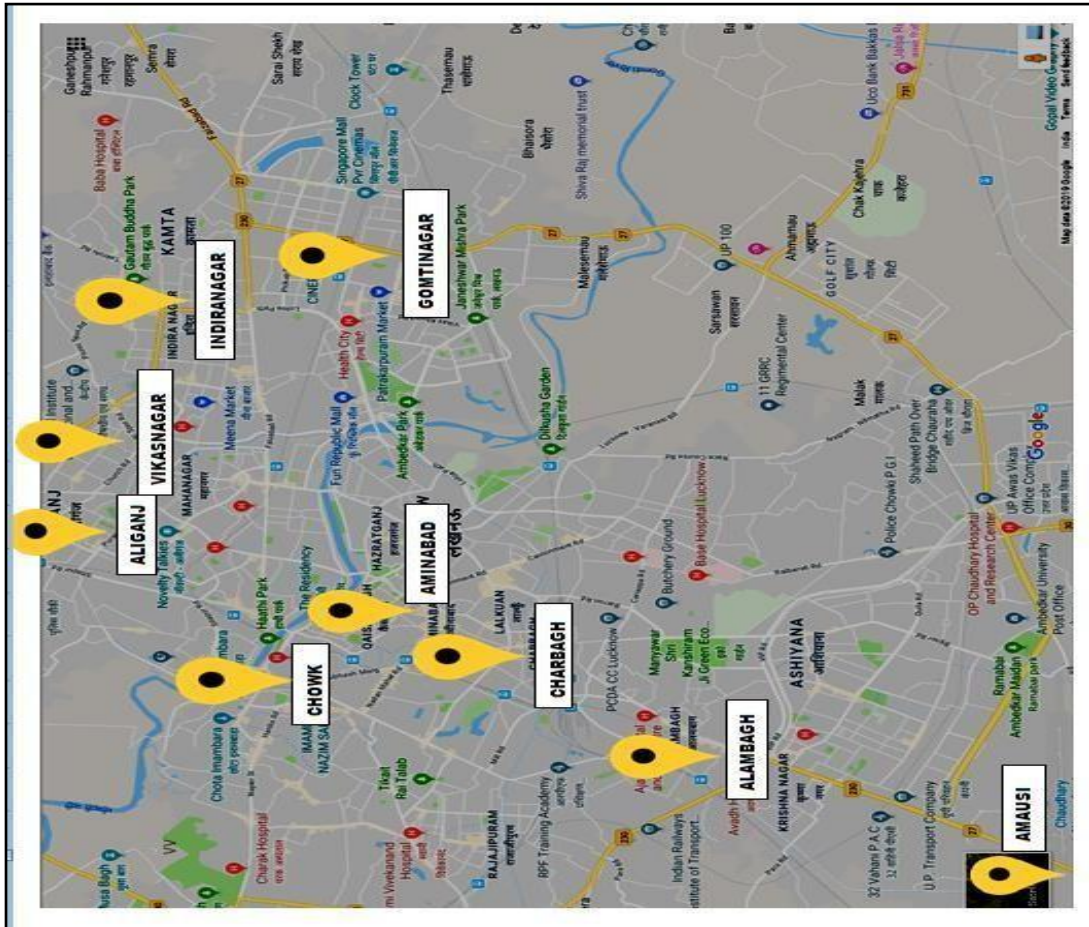


Fig: 1 Ambient Air Pollution Monitoring Locations in Lucknow City

About Lucknow city environment:-

According to the World Air Quality Report 2020, Lucknow is presently the ninth most polluted cities in the world with PM_{2.5} concentration docked at 86.2 microgram-11 times more than WHO limits. The city suffered an estimated economics loss of Rs 8,001 crore due to bad air quality and 6700 deaths in 2020. The air quality in the city is so bad that studies estimated that its residents could loss 10.3 years of their life expectancy on average if the pollution persists.

Air Quality Monitoring location		
S.NO	Type of Location	Study Sites
1.	Residential	Aliganj
2.	Commercial	Gomti Nagar
3.	Industrial	Talkatora

Guidelines for sampling and analysis of Sulphur dioxide in ambient air (Improved West and Gaeke method)

Purpose

The purpose of this protocol is to provide guidelines for monitoring and analysis of Sulphur dioxide in ambient air.

Standard

The national ambient air quality standards for Sulphur dioxide is presented in the table.

Pollutant	Time Weighted Average	Concentration in Ambient Air	
		Industrial, Residential, Rural and other Areas	Ecologically Sensitive Area (Notified by Central Government)
Sulphur Dioxide (SO ₂), µg/m ³	Annual * 24 Hours	50	20
	**	80	80

* 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 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.

West & Gaeke Method (IS 5182 Part 2 Method of Measurement of Air Pollution: Sulphur dioxide).

Sulphur dioxide from air is absorbed in a solution of potassium tetrachloro-mercurate (TCM). A dichlorosulphitomercurate complex, which resists oxidation by the oxygen in the air, is formed. Once formed, this complex is stable to strong oxidants such as Principle of the method

Modified ozone and oxides of nitrogen and therefore, the absorber solution may be stored for some time prior to analysis. The complex is made to react with para-rosaniline and formaldehyde to form the intensely colored pararosaniline methylsulphonic acid. The absorbance of the solution is measured by means of a suitable spectrophotometer.

Instrument/Equipment

The following items are necessary to perform the monitoring and analysis of nitrogen dioxide in ambient air:

Analytical balance:

Vacuum pump: Capable of maintaining an air pressure differential greater than 0.7 atmosphere at the desired flow rate

Calibrated flow-measuring device to control the airflow from 0.2 to 1 l/min.

Absorber: all glass midjet impinger.

Spectrophotometer: Capable of measuring absorbance at 560 nm equipped with 1 cm path length cells.

Glass wares: low actinic glassware must be used for analysis

Reagents / Chemicals

All the chemicals should meet specifications of Analytical Reagent grade

Distilled water

Mercuric chloride

Potassium chloride / Sodium chloride

EDTA di sodium salt

Absorbing Reagent, 0.04 M Potassium Tetrachloro mercurate (TCM) - Dissolve 10.86 g, mercuric chloride, 0.066 g EDTA, and 6.0 g potassium chloride or sodium chloride 4.68 gm in water and bring to the mark in a 1 litre volumetric flask. Caution: highly poisonous if spilled on skin, flush off with water immediately. The pH of this reagent should be approximately 4.0 but, it has been shown that there is no appreciable difference in collection efficiency over the range of pH 5 to pH 3. The absorbing reagent is normally stable for six months. If, a precipitate forms, discard the reagent after recovering the mercury.

Sulphamic Acid (0.6%) - Dissolve 0.6 g sulphamic acid in 100 ml distilled water. Prepare fresh daily.

Formaldehyde (0.2%) - Dilute 5 ml formaldehyde solution (36-38%) to 1 litre with distilled water. Prepare fresh daily.

Purified Pararosaniline Stock Solution (0.2% Nominal) Dissolve 0.500 gm of specially purified pararosaniline (PRA) in 100 ml of distilled water and keep for 2 days (48 hours).

Pararosaniline Working Solution - 10 ml of stock PRA is taken in a 250 ml volumetric flask. Add 15 ml conc. HCL and make up to volume with distilled water.

Stock Iodine Solution (0.1 N) - Place 12.7 g iodine in a 250 ml beaker, add 40 g potassium iodide and 25 ml water. Stir until all is dissolved, then dilute to 1 litre with distilled water.

Iodine Solution (0.01 N) - Prepare approximately 0.01 N iodine solution by diluting 50 ml of stock solution to 500 ml with distilled water.

Starch Indicator Solution - Triturate 0.4 gm soluble starch and 0.002 g mercuric iodide preservative with a little water and add the paste slowly to 200 ml boiling water. Continue boiling until the solution is clear, cool, and transfer to a glass-stoppered bottle.

Potassium iodate-

Stock Sodium Thiosulfate Solution (0.1 N) - Prepare a stock solution by placing 25 g sodium thiosulfate pentahydrate in a beaker, add 0.1 g sodium carbonate and dissolve using boiled, cooled distilled water making the solution up to a final volume of 1 litre. Allow the solution to stand one day before standardizing.

To standardize, accurately weigh to the nearest 0.1 mg, 1.5 g primary standard potassium iodate dried at 180°C, dissolve, and dilute to volume in a 500 ml volumetric flask. Into a 500 ml Iodine flask, transfer 50 ml of iodate solution by pipette. Add 2 g potassium iodide and 10 ml of N hydrochloric acid and stopper the flask. After 5 min, titrate with stock thiosulfate solution to a pale yellow. Add 5 ml starch indicator solution and continue the titration until the blue colour disappears. Calculate the normality of the stock solution.

Sodium Thiosulphate Titrant (0.01 N) - Dilute 100 ml of the stock thiosulfate solution to 1 litre with freshly boiled and cooled distilled water.

Standardized Sulphite Solution for Preparation of Working Sulphite- **TCM Solution** - Dissolve 0.30 g sodium metabisulphite ($\text{Na}_2\text{S}_2\text{O}_5$) or 0.40g sodium sulphite (Na_2SO_3) in

500 ml of recently boiled, cooled, distilled water. Sulphite solution is unstable; it is, therefore, important to use water of the highest purity to minimize this instability. This solution contains the equivalent of 320-400 $\mu\text{g/ml}$ of SO_2 .

Working Sulphite-TCM Solution - Measure 2 ml of the standard solution into a 100 ml volumetric flask by pipette and bring to mark with 0.04 M TCM. Calculate the concentration of sulphur dioxide in the working solution in micrograms of sulphur dioxide per millilitre. This solution is stable for 30 days if kept in the refrigerator at 5°C . If not kept at 5°C , prepare fresh daily.



Fig.1.1 Preparation of solution



Fig. 1.2 showing the standard solution for calibration

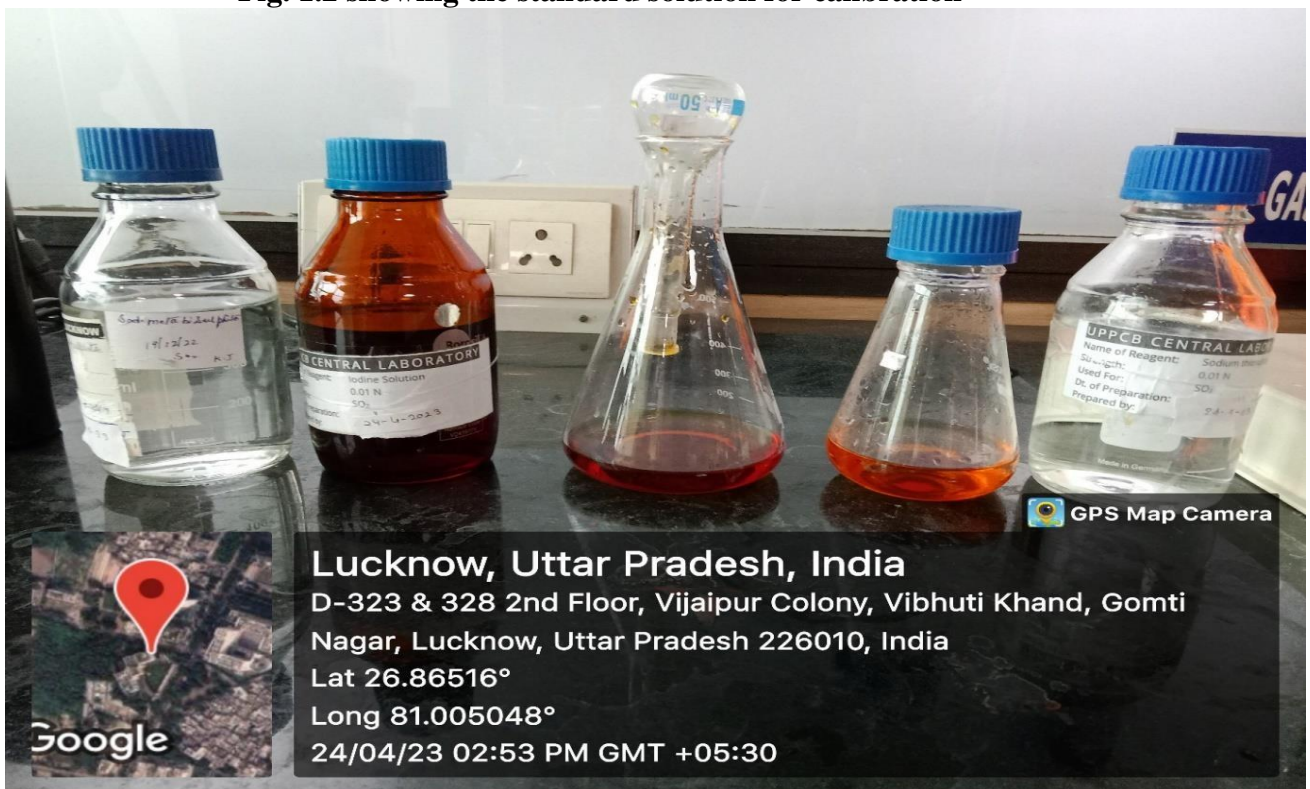


Fig.1.3 chemical used in preparation of solution

Sampling

The sampling is the process in which the sample is taken by the person for the analysis. Before sampling it is important to clean the bottle that is used in sampling because if in any contamination found in the bottle then the result affected.

The sampling box in which the cylinder are fitted is fill with ice or cold water it quit or stop warm of cylinder that's why the sample are not affected by the any factor .

Place 30 ml of absorbing solution in an impinger and sample for four hours at the flow rate of 1 L/min. After sampling measure the volume of sample and transfer to a sample storage bottle.

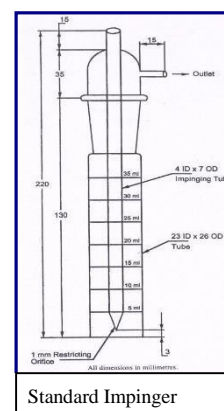


Fig1.4.Sampling of SO_x & NO_x.

Analysis

Replace any water lost by evaporation during sampling by adding distilled water up to the calibration mark on the absorber. Mix thoroughly, pipette out 10 ml of the collected sample into a 25 ml volumetric flask. Add 1 ml 0.6% .sulphamic acid and allow reacting for 10 minutes to destroy the nitrite resulting from oxides of nitrogen. Add 2 ml of 0.2% formaldehyde solution and 2 ml pararosaniline solution and make up to 25 ml with distilled water. Prepare a blank in the same manner using 10 ml of unexposed absorbing reagent.

After a 30 min color development interval and before 60 minutes, measure and record the absorbance of samples and reagent blank at 560 nm. Use distilled water; not the reagent blank, as the optical reference.

Calibration

The actual concentration of the sulphite solution is determined by adding excess iodine and back titrating with standard sodium thiosulfate solution. To back-titrate, measure, by pipette, 50 ml of the 0.01 N iodine solution into each of two 500 ml iodine flasks A and B. To flask a (blank) add 25 ml distilled water and into flask B (sample) measure 25 ml sulphite solution by pipette. Stopper the flasks and allow to react for 5 minutes. Prepare the working sulphite-TCM solution at the same time iodine solution is added to the flasks. By means of a burette containing standardized 0.01 N thiosulfate, titrate each flask in turn to a pale yellow. Then add 5 ml starch solution and continue the titration until the blue color disappear.



Fig. 1.5 Preparation of standard calibration curve for SO₂

Preparation of Standards

Measure 0.5 ml, 1.0 ml, 1.5 ml, 2.0 ml, 2.5 ml, 3.0 ml, 3.5 ml and 4.0 ml of working sulphite TCM solution in 25 ml volumetric flask. Add sufficient TCM solution to each flask to bring the volume to approximately 10 ml. Then add the remaining reagents as described in the procedure for analysis. A reagent blank with 10 ml absorbing solution is also prepared. Read the absorbance of each standard and reagent blank.

Standard Curve

Plot a curve absorbance (Y axis) versus concentration (X axis). Draw a line of best fit and determine the slope. The reciprocal of slope gives the calibration factor (CF).

Calculation

Concentration of sulphite solution:

$$C = \frac{(V1-V2) \times N \times K}{V}$$

Where,

- C = SO₂ concentration in $\mu\text{g/ml}$
- V1 = Volume of thiosulfate for blank, ml
- V2 = Volume of thiosulfate for sample, ml
- N = Normality of thiosulfate
- K = 32000 (Milliequivalent weight SO₂/μg)
- V = Volume of standard sulphite solution, ml

$$C (\text{SO}_2 \mu\text{g/m}^3) = (A_s - A_b) \times \text{CF} \times V_s / V_a \times V_t$$

Where,

- C SO₂ = Concentration of Nitrogen dioxide, $\mu\text{g/m}^3$
- A_s = Absorbance of sample
- A_b = Absorbance of reagent blank
- CF = Calibration factor
- V_a = Volume of air sampled, m³
- V_s = Volume of sample, ml
- V_t = Volume of aliquot taken for analysis, ml

Quality Control

Quality Control (QC) is the techniques that are used to fulfill requirements for quality. The QC procedures for the air sampling and monitoring sections of this protocol include preventative maintenance of equipment, calibration of equipment, analysis of field blanks and lab blanks.

FLOW CHART FOR MEASUREMENT OF SULPHUR DIOXIDE
Place 30 ml of absorbing media in an impinge <input type="checkbox"/>
Connect it to the gas-sampling manifold of gas sampling device(RDS/HVS). <input type="checkbox"/>
Draw air at a sampling rate of 1 lpm for four hours <input type="checkbox"/>
Check the volume of sample at the end of sampling and record it <input type="checkbox"/>
Transfer the exposed samples in storage bottle and preserve <input type="checkbox"/>
Prepare calibration graph as recommended in method <input type="checkbox"/>
Take 10/20 ml. aliquot of sample in 25 ml. Vol. Flask <input type="checkbox"/>
Take 10/20 ml. of unexposed sample in 25 ml. Vol. Flask (blank) <input type="checkbox"/>
Add 1 ml Sulphamic acid. Keep it 10 minutes <input type="checkbox"/>
Add 2 ml formaldehyde <input type="checkbox"/>
Add 2 ml working PRA <input type="checkbox"/>
Make up to mark (25 ml.) with distilled water. <input type="checkbox"/>
Keep it 30 minutes for reaction <input type="checkbox"/>
Set Zero of spectrophotometer with Distilled water <input type="checkbox"/>
Measure absorbance at 560 nm <input type="checkbox"/>
Calculate concentration using calibration graph <input type="checkbox"/>
Calculate concentration of Sulphur Dioxide in $\mu\text{g}/\text{m}^3$

Guidelines for sampling and analysis of Nitrogen dioxide in ambient air **(Modified Jacob and Hochheiser Method)**

Purpose

The purpose of this protocol is to provide guidelines for monitoring of nitrogen dioxide in ambient.

Standard

The national ambient air quality standard for nitrogen dioxide is presented in the table:

Pollutant	Time Weighted Average	Concentration in Ambient Air	
		Industrial, Residential, Rural and other Areas	Ecologically Sensitive Area (Notified by Central Government)
Nitrogen dioxide (NO ₂), µg/m ³	Annual * 24 Hours **	40	30
		80	80
* 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 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.			

Principle of the method

Modified Jacobs & Hochheiser Method (IS 5182 Part 6 Methods for Measurement of Air Pollution: Oxides of nitrogen).

Ambient nitrogen dioxide (NO₂) is collected by bubbling air through a solution of sodium hydroxide and sodium arsenite. The concentration of nitrite ion (NO₂⁻) produced during sampling is determined colorimetrically by reacting the nitrite ion with phosphoric acid, sulfanilamide, and N-(1-naphthyl)- ethylenediamine di-hydrochloride (NEDA) and measuring the absorbance of the highly coloured azo-dye at 540 nm.

Instrument/Equipment

The following items are necessary to perform the monitoring and analysis of nitrogen dioxide in ambient air:

Analytical balance:

Vacuum pump: Capable of maintaining a vacuum of at least 0.6 atmospheres.

Across the flow control device. Flow control device capable of maintaining a Constant flow of 200-1000 ml per minute through the sampling solution.

Calibrated flow measuring device: To control the airflow from 0.2 to 1 l/min.

Absorber: a midget impinger .

Spectrophotometer: Capable of measuring absorbance at 540 nm equipped with 1 cm path length cells.

Glass wares: low actinic glassware must be used for analysis.

Reagents / Chemicals

All the chemicals should meet specifications of ACS Analytical Reagent grade Distilled water, Sodium hydroxide, Sodium Arsenite .Absorbing solution (Dissolve 4.0 g of sodium hydroxide in distilled water, add 1.0 g of sodium Arsenite, and dilute to 1,000 ml with distilled water).

Sulphanilamide - Melting point 165 to 167°C.

N-(1-Naphthyl)-ethylenediamine Di-hydrochloride (NEDA) - A 1% aqueous solution should have only one absorption peak at 320 nm over the range of 260-400 nm. NEDA showing more than one absorption peak over this range is impure and should not be used.

Hydrogen Peroxide - 30%.

Phosphoric Acid - 85%.

Sulphanilamide Solution - Dissolve 20 g of sulphanilamide in 700 ml of distilled water. Add, with mixing, 50 ml of 85% phosphoric acid and dilute to 1,000 ml. This solution is stable for one month, if refrigerated.

NEDA Solution - Dissolve 0.5 g of NEDA in 500 ml of distilled water. This solution is stable for one month, if refrigerated and protected from light.

Hydrogen Peroxide Solution - Dilute 0.2 ml of 30% hydrogen peroxide to 250 ml with distilled water. This solution may be used for one month, if, refrigerated and protected from light.

Sodium nitrite - Assay of 97% NaNO_2 or greater

Sodium Nitrite stock solution (1000 $\mu\text{g NO}_2/\text{ml}$)

Sodium Nitrite solution (10 $\mu\text{g NO}_2/\text{ml}$.)

Sodium Nitrite working solution (1 $\mu\text{g NO}_2/\text{ml}$) (Dilute with absorbing reagent, prepare fresh daily) .

Sampling

Place 30 ml of absorbing solution in an impinger and sample for four hour at the flow rate of 0.2 to 1 L/min. After sampling measure the volume of sample and transfer to a sample storage bottle.

Analysis

Replace any water lost by evaporation during sampling by adding distilled water up to the calibration mark on the absorber, mix thoroughly. Pipette out 10 ml of the collected sample into a 50 ml volumetric flask. Pipette in 1 ml of hydrogen peroxide solution, 10 ml of sulphanilamide solution, and 1.4 ml of NEDA solution, with thorough mixing after the addition of each reagent and make up to 50 ml with distilled water. Prepare a blank in the same manner using 10 ml of unexposed absorbing reagent.

After a 10 min color development interval, measure and record the absorbance of samples and reagent blank at 540 nm. Use distilled water; not the reagent blank, as the optical reference Samples with an absorbance greater than 1.0 must be re-analyzed after diluting an aliquot of the collected samples with an equal quantity of unexposed absorbing reagent. A randomly selected 5-10% of the samples should be re-analyzed as a part of an internal quality assurance program.

Calibration

The calibration of sample with the help of calibrator machine to set the light intensity at a level and change with the help of controller.



Fig.2 Calibration of sample.

Preparation of Standards

Pipette 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 15 and 20 ml of working standard solution into 50 ml volumetric flask. Fill to 20 ml mark with absorbing solution. A reagent blank with 10 ml absorbing solution is also prepared. Add reagents to each volumetric flask as in the procedure for analysis. Read the absorbance of each standard and reagent blank against distilled water reference.

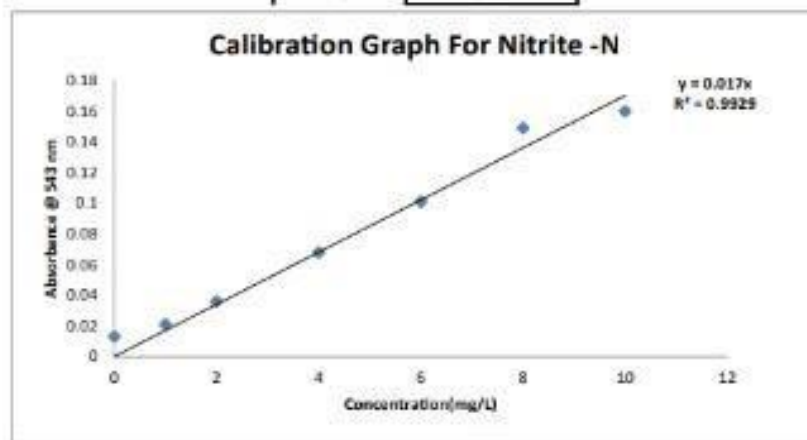
Standard Curve:

Plot a curve absorbance (Y axis) versus concentration (X axis). Draw a line of best fit and determine the slope. The reciprocal of slope gives the calibration factor (CF).

Central Laboratory
U.P. Pollution Control Board, Lucknow

Calibration Graph For Nitrite-N

Concentration (mg/L)	absorbance @543nm
0	0.013
1	0.021
2	0.036
4	0.058
6	0.101
8	0.149
10	0.16



Prepared By:

Supervised By:

i/c Central lab

Mrs. Usha Kiran (ASO)

Mrs. Manju Gupta

Date: 12/01/16

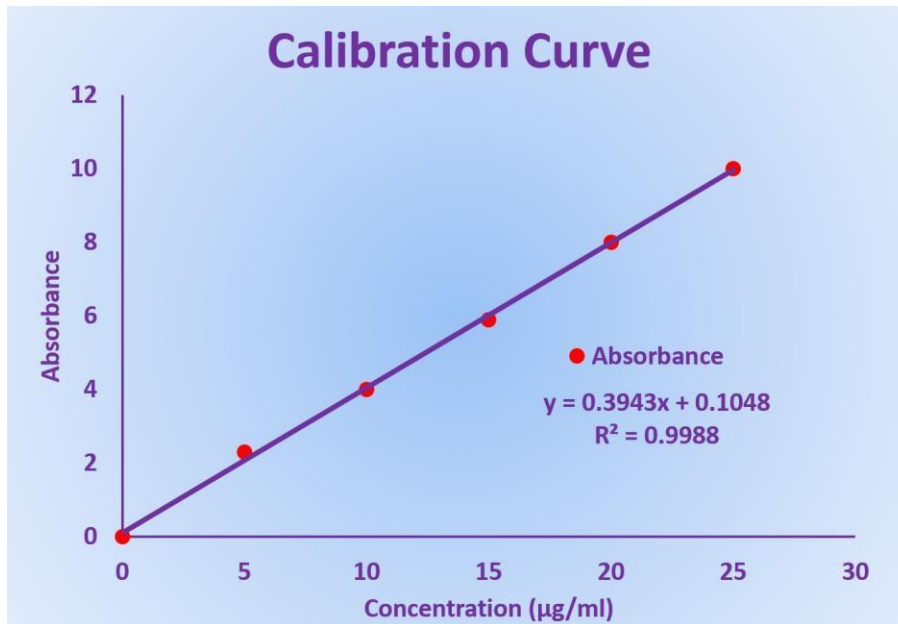


Fig.2.1 Standard curve

Calculation

$C (\text{NO}_2 \mu\text{g}/\text{m}^3) = (A_s - A_b) \times \text{CF} \times V_s / V_a \times V_t \times 0.82$ Where,

$C \text{ NO}_2$ = Concentration of Nitrogen dioxide, $\mu\text{g}/\text{m}^3$

A_s = Absorbance of sample

A_b = Absorbance of reagent

BlankCF = Calibration factor

V_a = Volume of air sampled, m^3 V_s = Volume of sample, ml

V_t = Volume of aliquot taken for analysis, ml

0.82 = Sampling efficiency

Quality Control

Quality Control (QC) is the techniques that are used to fulfil requirements for quality. The QC procedures for the air sampling and monitoring sections of this protocol include preventative maintenance of equipment, calibration of equipment, analysis of field blanks and lab blanks.

FLOW CHART FOR MEASUREMENT OF NITROGEN DIOXIDE	
Place 30 ml of absorbing media in an impinger	<input type="checkbox"/>
Connect it to the gas sampling manifold of gas sampling device(RDS/HVS).	<input type="checkbox"/>
Draw air at a sampling rate of 1 lpm for four hours	<input type="checkbox"/>
Check the volume of sample at the end of sampling and record it	<input type="checkbox"/>
Transfer the exposed samples in storage bottle and preserve	<input type="checkbox"/>
Prepare calibration graph as recommended in method	<input type="checkbox"/>
Take 10 ml. aliquot of sample in 50 ml. Vol. Flask	<input type="checkbox"/>
Take 10 ml. of unexposed sample in 50 ml. Vol. Flask (blank)	<input type="checkbox"/>
Add 1 ml hydrogen peroxide,	<input type="checkbox"/>
Add 10 ml sulphanilamide	<input type="checkbox"/>
Add 1.4 ml NEDA	<input type="checkbox"/>
Make up to mark (50 ml.) with distilled water.	<input type="checkbox"/>
Keep it 10 minutes for reaction	<input type="checkbox"/>
Set Zero of spectrophotometer with Distilled water	<input type="checkbox"/>
Measure absorbance at 540 nm	<input type="checkbox"/>
Calculate concentration using calibration graph	<input type="checkbox"/>
Calculate concentration of Nitrogen Dioxide in $\mu\text{g}/\text{m}^3$	

Guidelines for sampling and analysis of Particulate Matter (PM₁₀) in ambient air (Gravimetric Method)

Purpose

The purpose of this protocol is to provide guidelines for monitoring and analysis of Particulate Matter PM₁₀ in ambient air.

Standard

The national ambient air quality standards for Particulate Matter PM₁₀ is presented in the table

Pollutant	Time Weighted Average	Concentration in Ambient Air	
		Industrial, Residential, Rural and other Areas	Ecologically Sensitive Area (Notified by Central Government)
Particulate Matter, PM ₁₀ , $\mu\text{g}/\text{m}^3$	Annual * 24 Hours **	60	60
		100	100
* 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 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.			

Principle of the method

Air is drawn through a size-selective inlet and through a 20.3 X 25.4 cm (8 X 10 in) filter at a flow rate, which is typically 1132 L/min. Particles with aerodynamic diameter less than the cut-point of the inlet are collected, by the filter. The mass of these particles is determined by the difference in filter weights prior to and after sampling. The concentration of PM₁₀ in the designated size range is calculated by dividing the weight gain of the filter by the volume of air sampled.

Instrument/Equipment

The following items are necessary to perform the monitoring and analysis of particulate.

Matter PM₁₀ in ambient air:

Analytical balance:

Sampler: High Volume Sampler with size selective inlet for PM₁₀ and automatic volumetric flow control.

Calibrated flow-measuring device to control the airflow at 1132 l/min.

Top loading orifice kit.

Reagents / Chemicals

Filter Media – A Glass fibre filter of 20.3 X 25.4 cm (8 X 10 in) size

Sampling

Field Sampling - Tilt back the inlet and secure it according to manufacturer's instructions. Loosen the faceplate wing nuts and remove the faceplate. Remove the filter from its jacket and center it on the support screen with the rough side of the filter facing upwards. Replace the faceplate and tighten the wing nuts to secure the rubber gasket against the filter edge. Gently lower the inlet. For automatically flow-controlled units, record the designated flow rate on the data sheet. Record the reading of the elapsed time meter. The specified length of sampling is commonly 8 hours or 24 hours. During this period, several reading (hourly) of flow rate should be taken.

After the required time of sampling, record the flow meter reading, take out the filter media from the sampler, and put in a container or envelope.



Fig.3 Dust Sampler Machine

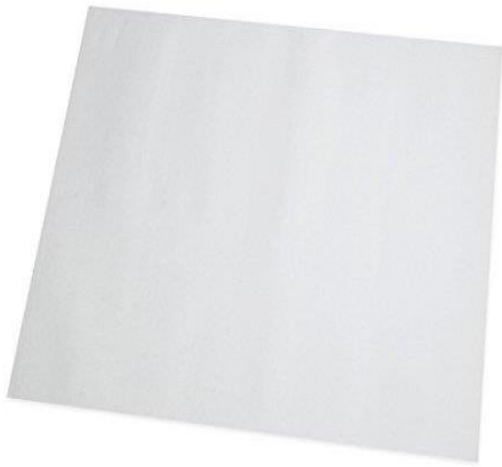


Fig.3.1 Before Sampling



Fig.3.2 After 8 hrs Sampling

Analysis

Filter inspection: Inspect the filter for pin holes using a light table. Loose particles should be removed with a soft brush. Apply the filter identification number or a code to the filter if it is not a numbered. Condition the filter in conditioning room maintained within 20-30.

□ C and 40-50% relative humidity or in an airtight desiccator for 24 hours. Take initial weight of the filter paper (W_i) before sampling. Condition the filter after sampling in conditioning room maintained /within 20-30.

□ C and 40-50% relative humidity or in an airtight desiccator for 24 hours. Take final weight of the filter paper (W_f).

Calibration

Periodical calibration of the sampler is being done by Orifice Transfer Standard - The PM_{10} sampler calibration orifice consists of a 3.175 cm (1.25 in) diameter hole in the end cap of 7.62 cm (3 in) diameter by 20.3 cm (8 in) long hollow metal cylinder. This orifice is mounted tightly to the filter support in place of the inlet during calibration. A small tap on the side of the cylinder is provided to measure the pressure drop across the orifice. A flow rate of 1132 L/min through the orifice typically results in a pressure difference of several inches of water. The relationship between pressure difference and flow rate is established via a calibration curve derived from measurements against a primary standard such as a Roots meter at standard temperature and pressure. Flow resistances that simulate filter resistances are introduced at the end of the calibrator opposite the orifice by a set of perforated circular disks.

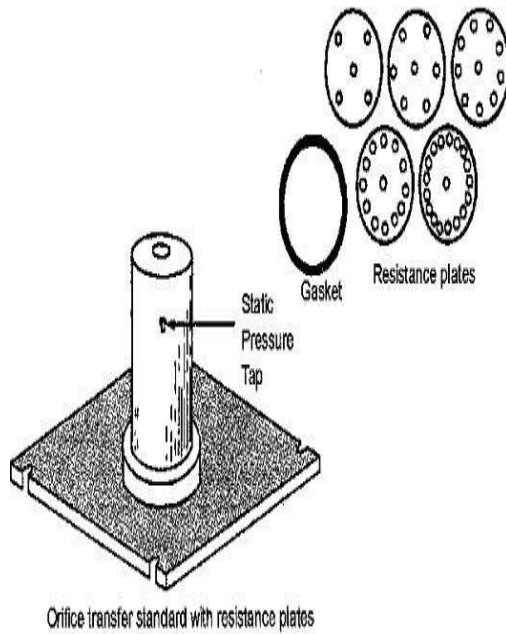


Fig.3.3 Top loading Orifice kit

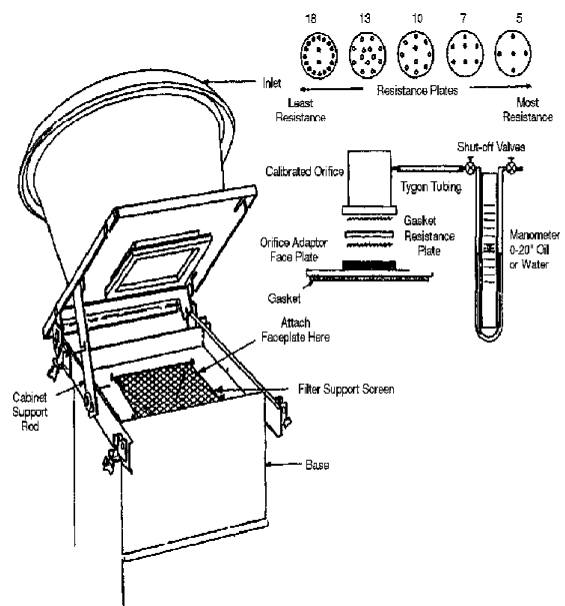


Fig.3.4 Calibration set up

Calculation

$C_{PM10} \mu\text{g}/\text{m}^3 = (W_f - W_i) \times 106 / V$ Where,
 C_{PM10} = Concentration of Nitrogen dioxide, $\mu\text{g}/\text{m}^3$
 W_f = Initial weight of filter in g
 W_i = Initial weight of filter in g
 106 = Conversion of g to μg
 V = Volume of air sampled, m^3

Quality Control

Quality Control (QC) is the techniques that are used to fulfill requirements for quality. The QC procedures for the air sampling and monitoring sections of this protocol include preventative maintenance of equipment, calibration of equipment, analysis of field blanks and lab blanks.

FLOW CHART FOR MEASUREMENT OF PM₁₀
Check the filter for any physical damages <input type="checkbox"/>
Mark identification number on the filter <input type="checkbox"/>
Condition the filter in conditioning room / desiccator for 24 hours <input type="checkbox"/>
Record initial weight <input type="checkbox"/>
Place the filter on the sampler <input type="checkbox"/>
Run the sampler for eight hours <input type="checkbox"/>
Record the flow rate on hourly basis <input type="checkbox"/>
Remove the filter from the sampler <input type="checkbox"/>
Keep the exposed filter in a proper container <input type="checkbox"/>
Record the total time of sampling & average flow rate <input type="checkbox"/>
Again condition the filter in conditioning room / desiccator for 24 hours <input type="checkbox"/>
Record final weight <input type="checkbox"/>
Calculate the concentration of PM ₁₀ in $\mu\text{g}/\text{m}^3$

Guidelines for determination of PM_{2.5} in ambient air (Gravimetric Method)

Purpose

The purpose of this protocol is to provide guidelines for monitoring and analysis of Particulate Matter PM_{2.5} in ambient air.

Definition

PM_{2.5} refers to fine particles that are 2.5 micrometers (µm) or smaller in diameter. Ambient air is defined as any unconfined part of the Earth's atmosphere, that the surrounding outdoor air in which humans and other organisms live and breathe.

FRM – Federal Reference Method FEM – Federal Equivalent Method.

Standard

Pollutant	Time Weighted Average	Concentration in Ambient Air	
		Industrial, Residential, Rural and other Areas	Ecologically Sensitive Area (Notified by Central Government)
Particulate Matter, PM _{2.5} , µg/m ³	Annual * 24 Hours **	40	40
		60	60
<p>* Annual Arithmetic mean of minimum 104 measurements in a year at a particular site taken twice a week 24 hourly at uniform intervals.</p> <p>** 24 hourly or 8 hourly or 1 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.</p>			

Principle

An electrically powered air sampler draws ambient air at a constant volumetric flow rate (16.7 lpm) maintained by a mass flow / volumetric flow controller coupled to a microprocessor into specially designed inertial particle-size separator (i.e. cyclones or impactors) where the suspended particulate matter in the PM_{2.5} size ranges is separated for collection on a 47 mm polytetrafluoroethylene (PTFE) filter over a specified sampling period. Each filter is weighed before and after sample collection to determine the net gain due to the particulate matter. The mass concentration in the ambient air is computed as the total mass of collected particles in the PM_{2.5} size ranges divided by the actual volume of air sampled, and is expressed in µg/m³. The microprocessor reads averages and stores five-minute averages of ambient temperature, ambient pressure, filter temperature and volumetric flow rate. In Addition, the microprocessor calculates the average temperatures and pressure, Total volumetric flow for the entire sample run time and the coefficient of variation of the flow rate.

Interferences and Artefacts

The potential effect of body moisture or oils contacting the filters is minimized by using non-serrated forceps to handle the filters at all times. This measure also moderates interference due to static electricity.

Teflon filters accumulate a surface electrical charge, which may affect filter weight. Static electricity is controlled by treating filters with a "Static Master" static charge neutralizer

prior to weighing. Placement of filters on a “Static Master” unit is required for a minimum of 30 seconds before any filter can be weighed.

Moisture content can affect filter weight. Filters must be equilibrated for a minimum of 24 hours in a controlled environment prior to pre- and post- weighing. The balance room’s relative humidity must be maintained at a mean value range of $45 \pm 5 \%$ and its air temperature must be maintained at a mean value range of $25.0 \pm ^\circ\text{C}$.

Airborne particulate can adversely affect accurate mass measurement of the filter. Filters undergoing conditioning should not be placed within an airflow path created by air conditioning ductwork, computer printers, or frequently opened doorways. Cleaning laboratory bench-tops and weighing areas daily, installing “sticky” floor mats at doorway entrances to the balance room and wearing clean lab coats over regular clothing can further minimize dust contamination.

Precision and Accuracy

The performance segment of the PM_{2.5} FRM specifies strict guidelines for controls that must be observed, as well as the range of precision and accuracy of those controls. The flow rate through the instrument is specified as 16.67 lpm ($1 \text{ m}^3/\text{hr}$). This flow must be volumetrically controlled to a precision of 5% and an accuracy of 2%. The flow control must be upgraded at least every 30 seconds and recorded (logged) every five minutes. Barometric pressure, ambient temperature and filter temperature should be measured on the same schedule. Filter temperature, it must not exceed the ambient temperature by more than 5°C for more than 30 minutes. A fan blowing filtered ambient air through the enclosure provides the necessary cooling effect. It is necessary for the entire apparatus to provide accurate performance over a temperature range of -20 to 50°C . The supporting run-time (interval) data, which are stored in detailed 5- minute intervals in the sampler’s microprocessor, as well as 24-hour integrated performance (filter) data, must be capable of being extracted at the completion of a 24-hour run. The FRM mandates the provision of an RS232 port for this purpose. Data may be extracted to a portable computer.

Mass of the filter deposit, flow rate through the filter, and sampling time have typical precision of $\pm 0.2 \text{ mg}$, $\pm 5\%$, and ± 30 seconds, respectively. These uncertainties combine to yield a propagated precision of approximately $\pm 5 \%$ at $10 \mu\text{g}/\text{m}^3$ and approximately $\pm 2\%$ at $100 \mu\text{g}/\text{m}^3$.

6.0 Sitting Requirements

Samplers should be sited to meet the goals of the specific monitoring project. For routine sampling to determine compliance with the National Ambient Air Quality Standards (NAAQS), sampler sitting is described in CPCB guidelines shall apply

The monitoring should be done at outside the zone of influence of sources located within the designated zone of representation for the monitoring site.

Height of the inlet must be 3 – 10 m above the ground level. And at a suitable distance from any direct pollution source including traffic.

Large nearby buildings and trees extending above the height of the monitor may present barriers or deposition surfaces for PM. Distance of the sampler to any air flow obstacle i.e. buildings, must be more than two times the height of the obstacle above the sampler.

There should be unrestricted airflow in three of four quadrants.

Certain trees may also be sources of PM in the form of detritus, pollen, or insect parts.

These can be avoided by locating samplers by placing them > 20 m from nearby trees.

If collocated sampling has to be performed the minimum distance between two Samplers should be 2 m.

Apparatus and Materials

Sampling equipment designated as FRM (Federal Reference Method) or FEM (Federal Equivalent Method) Certified Flow Transfer Standard for Flow Calibration

Following established EPA methods and procedures, all calibration transfer standards (i.e. temperature, pressure and flow) must be certified against traceable standards at least once per year. Calibration of these transfer standards will be conducted by the transfer standard manufacturer.

Certified Standards for Pressure and Temperature (Optional) Electronic microbalance with a minimum resolution of 0.001 mg and a precision of ± 0.001 mg, supplied with a balance pan. The microbalance must be positioned on a vibration-damping balance support table.

Calibration weights, utilized as Mass Reference Standards, should be non-corroding, range in weight from 100 mg to 200 mg, and be certified as traceable to NIST mass standards. The weights should be ASTM Class 1 category with a tolerance of 0.025 mg.

Non-serrated forceps for handling filters. Non-metallic, non-serrated forceps for handling weights. Digital timer/stopwatch. 47 mm Filter: Teflon membrane, 46.2 mm effective diameter with a polypropylene support ring or filters as recommended by FRM / FEM sampler manufacturer. Filter support cassettes and covers. Filter equilibration racks.

Relative Humidity / Temperature recorder. NIST-certified or ISO traceable Hygrometer for calibration of relative humidity readings. NIST-certified ISO traceable Thermometer for calibration of temperature readings. Light box. Radioactive (alpha particle) Polonium-210 (“Static Master”) antistatic strips for static charge neutralization however static charge gives low- moderate interference in stability of reading of balance.

Antistatic, nitrate-free, phosphate-free, sulphate-free, and powder free vinyl gloves.

Plastic petri-slide filters containers (Filter Cassette). Zip-lock plastic bags, 6”x 9”.

Disposable laboratory wipes. Filter equilibration cabinets.

Impactor oil/grease

Sampling and Analytical Procedure

Calibration and performance check of Sampler

External Leak Check:

Upon initial installation of the sampler, following sampler repair or maintenance and at least monthly, perform a sampler external leak check according to the manufacturer’s guidelines.

Internal Leak Check:

Upon initial installation of the sampler, following sampler repair or maintenance, and at least monthly, perform a sampler internal leak check according to the manufacturer’s guidelines

Single-point Ambient Temperature and Filter Temperature Verification Check:

A single-point temperature verification check of both the ambient temperature and filter temperature sensors must be performed at least once every month. The Temperature check

is performed following manufacturer's guidelines

Ambient Temperature Calibration:

The ambient temperature calibration is to be performed upon initial installation, yearly after site installation after any major maintenance that might affect the temperature reading, and at any time thereafter when the sampler fails a verification check following manufacturer's guidelines.

Filter Temperature Calibration

The filter temperature calibration is to be performed upon initial installation, yearly after site installation, and at any time thereafter when the sampler fails either a single-point or multi-point temperature verification check. To perform the temperature calibrations of filter follow the manufacturer's instructions.

Pressure Verification Check

Single-point pressure verification must be performed at least once every month. The pressure check is performed following manufacturer's instructions.

Pressure Calibration

The pressure calibration is to be performed upon initial installation, yearly after site installation, and at any time thereafter when the sampler fails a single-point pressure verification check. Pressure calibration shall be performed following manufacturers Instructions.

Single-point Flow Verification Check

A single-point flow verification check must be performed at least every month. The flow check is performed following manufacturer's instructions.

Multi-Point Flow Calibration Procedure

A multi-point flow calibration must be performed upon initial installation and once per year thereafter. In addition, the multi-point calibration must be performed whenever a single-point flow verification check indicates that the sampler flow deviates from the flow transfer standard by more than $\pm 4\%$. The multi-point calibration is performed following manufacturer's instructions.

Selection and Procurement of Filters

The quality of filter papers to be used should technically meet the desired specifications. It is preferable to prepare the estimate for whole requirement and order the same in bulk with a request to supply the same batch/lot of filters to control analytical quality and blank values. During the selection of filters following points should be considered:

- Mechanical stability;
- Chemical stability;

- Particle or gas sampling efficiency;
- Flow resistance;
- Loading capacity;
- Blank values;
- Artefact formation;
- Compatibility with analysis method; and
- Cost and availability.

47 mm (diameter) Teflon (PTFE) filter paper with Polypropylene support ring manufactured by M/s Whatman or M/s Pall Life Sciences or equivalent having 2 µm pore sizes. The filter papers should have very low background concentrations for ion and elements.

Filter Inspection and Conditioning of Filter Papers

Filter papers selected for different analytical objectives should be conditioned by following steps:

- Inspect all the filter papers for holes or cracks. Reject, if any deformity is found.
- Note down the batch/lot in log sheet.
- Label all the filters following a general lab coding technique, which should be unique to represent a sample.
- Put the marked filters in petri dishes.
- Use always proper (blunt) tweezers/forceps (made of non-reactive material) to handle the filter papers in lab and field as well.
- Prepare a sample-tracking sheet for each filter paper or a batch of filter paper.
- Filter Inspection and Stability

To equilibrate, the filters are transferred from their sealed manufacturer's packaging to a filter-handling container such as a plastic petri-slide. The filters are handled with non-serrated forceps. Lab personnel must wear vinyl gloves as secondary when filters are being prepared for conditioning and weighing. Before any filter is placed in a filter-handling container, it must be inspected for defects. This is done by an examination of the filter on a "light table". A filter must be discarded if any defects are identified. Specific defects to look for are:

- Pinhole – A small hole appearing as a distinct and obvious bright point of light when examined over a light table.
- Separation of ring – Any separation or lack of seal between the filter and the filter support ring.
- Chaff or flashing – Any extra material on the reinforcing ring or on the heat-seal area that would prevent an airtight seal during sampling.
- Loose materials – Any extra loose materials or dirt particles on the filter.
- Discoloration – Any obvious discoloration that might be evidence of contamination.
- Other – A filter with any imperfection not described above, such as irregular surfaces or other results of poor workmanship.

Filter Conditioning

A one-month storage period in a controlled environment, followed by one week equilibration in the weighing environment, found acceptable deviations in reweighing. Gravimetric measurement is the net mass on a filter by weighing the filter before and after sampling with a balance in a temperature and relative humidity controlled environment as described in SOPs. To minimize particle volatilization and aerosol liquid water bias, PM_{2.5} reference methods require that filters be equilibrated for 24 hours at a constant (within $\pm 5\%$) relative humidity 45 % and at a constant (within $\pm 2^\circ\text{C}$) temperature between 25°C. These filter equilibrium conditions are intended to minimize the liquid water associated with soluble compounds and to minimize the loss of volatile species.

Lot Blanks Check

Randomly select three filters as lot blanks from each new lot received and place in individual containers. Equilibrate the exposed filters in a filter equilibration cabinet in the Balance Room that allows air circulation, but still reduces extraneous airborne particles from settling on filters. Weigh lot blanks every 24 hours on a designated balance.

Record the lot number, filter number, mass, and dates of the lot blanks in the assigned quality control logbook. Once the mass difference between weighing is less than 0.015 mg for all three lot blanks, the filters have stabilized. Note the time taken from initial exposure of the filters to attainment of mass stability. This information is designated as the minimum equilibration period required before filters from the same lot can be pre-weighed and used for routine sampling. Once this minimum equilibration period is determined, the lot blanks become lab blanks which are set aside for long-term exposure in the same equilibration cabinet where routine samples, field blanks, and trip blanks are equilibrated prior to pre- or post-weighing.

Laboratory Conditions for Weighing

Gravimetric analysis of the filters needs to be performed with a microbalance. The sensitivity and reliability of the electro-balance is about + 0.001 mg or 1 μg . Though tolerances on re-weights of Teflon- membrane filters are typically ± 0.010 mg, these sensitive balances require isolation from vibration and air currents. Balances placed in laminar flow hoods with filtered air minimize contamination of filters from particles and gases in laboratory air. Electrostatic effects contribute another main interference in gravimetric analysis of filters. It is established that residual charge on a filter could produce an electrostatic discharge between the filter on the pan and the metal casing of the electro balance, which induces non-gravimetric forces. This charge can be removed from most filter media by exposing the filter to a low-level radioactive source (500 Pico curies of polonium-210) prior to and during sample weighing.

Electro Balance Controls and Calibration

Gravimetric mass analysis is performed using single pan electronic balance. If possible, polonium strip ionization units are used to reduce electrostatic effects in the weighing cavity and on individual filters. A segregated laboratory area is used to control human traffic and to stabilize the temperature and relative humidity of the weighing environment. The area is cleaned with a high efficiency vacuum cleaner, and a tacky floor covering is installed at the entrance to the sample handling room to minimize dust artifact. Gravimetric analysis of filters currently uses the difference method to determine the mass of the collected aerosol. The pre weight of each filter is measured prior to being sent into the

field for sampling. Once exposed and returned to the sample handling room, the filter is removed, petri dishes and the post weight of the filter is measured after conditioning. The mass of the aerosol is determined by calculating the difference between the pre and post weights.

Cleaning and Maintenance of the Sample Handling Room

The requirements for a sample handling room include a reduced dust environment, and, over the twenty-four hour period prior to analysis of exposed filters, temperature in the range of 25° C with variation less than $\pm 3^\circ$ C, and relative humidity 45% $\pm 5\%$. Every last working day, the sample handling room should be thoroughly cleaned, after insuring that all filters have been protected against contamination. To reduce fugitive dust levels, all surfaces are cleaned with a high efficiency vacuum. The floors are cleaned with a mild cleaning solution, if necessary. Finally, all work surfaces are cleaned with reagent grade alcohol (or another reagent grade solvent, if necessary) and Kimwipes™. This procedure reduces the possibility of contamination if a filter falls to the work surface. Following the Friday cleaning, no analysis shall occur for at least twenty-four hours to reduce the potential for contamination of filters by compounds used in the cleaning process.

Calibration and Maintenance of balance

The balance is cleaned and calibrated every day for ranges at the start of operation. It is also recalibrated if the balance fails a "zero" test that is performed periodically. A calibration log database is maintained for each balance. Significant events concerning the balance and any balance maintenance other than routine procedures are recorded in the log of the lab manager.

Cleaning

Regular cleaning should be performed as following:

- Clean the metal and plastic forceps with ethanol and a Kimwipe™.
- Clean the work surface around the balance with ethanol and a Kimwipe™.
- Clean the top surface and the strips of the anti-static ionizing units by gently rubbing with a Kimwipe™ wetted with ethanol. Do not neglect to clean the ionizing unit in the electro balance. Replace the clean ionizing unit in the center back of the balance cavity, and close the door on the weighing chamber (if polonium strip is used). Thorough Calibration of Balance (Once in 6 Months) .

Allow the balance to stabilize with no weights on the pan. The computer will automatically record the mass to the screen when the balance has stabilized; this is the "zero" mass. It should be within 0.010 mg of 0.000. If not, contact the lab manager (see step 3, section 4.3.2.1 for lab manager procedures).

Set the zero on the balance by pressing the tare button on the balance. This forces the "zero" mass to be exactly 0.000.

Calibrate the balance. Momentarily ground yourself by touching the balance casing. Use nylon forceps to remove the certified calibration weight from its container. Gently place it in the center and allow the mass reading to stabilize and stop decreasing. Take readings.

- Use a 200.000 mg or suitable mass of graded Calibration weight.
- Use a 20.000 mg or suitable mass graded Calibration weight.
- Remove the calibration weight from the bail, using the nylon forceps, and replace

it in its storage container.

- Check the calibration of the balance using the test weight. Momentarily ground yourself by touching the balance casing. Use the nylon forceps to remove the test weight from its container.
- Place the test weight in the center of the balance pan and allow the mass reading to stabilize and stop decreasing. The computer will record a reading to the screen when the balance has stabilized. The test weight is an old 50.000 gm calibration weight. Allow the balance to return to "zero." Compare the zero value and the value determined for the 50.000 mg mass to the expected values posted on the balance. If they exceed 02 micrograms, repeat the procedure. If variations greater than 10 micrograms are observed, report to the laboratory manager so that he/she can take appropriate action (section 4.3.2.1 step 3).
- On a random basis, but at least semiannually, the laboratory supervisor shall request a comparison of the normal calibration standards with a master set of reference standard masses maintained by the laboratory supervisor. After calibration, measure these 200.000, 50.000, and 20.000 mg standards and report their masses to the supervisor. The results are used to verify the integrity of the electro balance and the standard masses used in daily calibrations.
- The electro balance is available to run controls or for routine determination of mass.
- Linearity checks (Once in a year otherwise after every repair/shifting of balance). To run a linearity check on the balance (if the balance is suspected to be damaged), utilize the series of four standard weights stored in the lab manager's desk. The four weights, 200 mg, 100 mg, 50 mg, and 20 mg, must be weighed and a regression line developed. Take following steps for performing Linearity checks:
 - Use the nylon forceps to remove a weight from its container and place it on the weighing pan.
 - Wait until the balance has stabilized (approximately one minute). Then, record the displayed weight as the 'y' value and the certified mass as the 'x' value.
 - Remove the weight from the pan, using the plastic forceps, and replace it in its protective container.
 - Repeat steps (i) through (iii) for the other three weights.
 - Linearly regress the 'y' value versus the 'x' value. Calculate the r^2 value.
 - If the R^2 is not better than 0.995, the balance requires maintenance.

Stability Check of Balance (Once in Month)

To check the stability of the balance, reweigh the last 20 archived control filters, and develop a regression line comparing the re-weight values to the original values. Use following steps:

- Reweigh the series of 20 old controls filters on the suspect balance.
- Plot the re-weights versus the original weights.
- Derive the best line fit equation correlating the original weights to the re- weights.
- Calculate the standard deviation and the r^2 of the line fit.
- If the standard deviation is greater than ± 3 micrograms, and the r^2 is not better than 0.995, the balance should be carefully inspected and submitted for maintenance.

Daily Calibration of Balance

Internal Calibration should be performed daily before any Pre- or Post- sampling weighing.

Internal Calibration

Open the draft shield door for at least one minute to allow the balance- weighing chamber to equilibrate to room temperature, then, close the draft shield door. Press the “TARE” key when readout has stabilized to ensure zero-readout. The liquid crystal display (LCD) should display “0.000 mg”. Press the key for ensuring the internal calibration.

External Calibration

Open the draft shield door. Place a 100 mg working reference standard calibration weight onto the microbalance pan with non-metallic forceps. Close the draft shield door. Record the date, temperature and relative humidity of the balance room, and mass readout in the quality control logbook assigned to the microbalance. Remove the calibration weight and tare the microbalance as described above. Enter the calibration data into logbook records and assign to the calibration session in the quality control logbook assigned to the microbalance. External calibration must be performed for each day on which filters are pre-weighed and/or post- weighed.

Weighing of Filters

Take out pre-conditioned filters by forceps one by one and weigh properly. Record the mass in data sheet and log books against respective filter numbers or code. Always use gloved hands and blunt tweezers to handle filters.

Replace and close the filter container (Petri dishes). Weigh one Control Filters (Archived one) with each batch of ten weighing. Keep separate controls for Pre (Blank filter) and Post (Exposed) sampling filters? Put the values of all control measurement in Quality Control Charts against dates. Put Lab code on from Plastic petri-slide filter containers (Filter Cassette). Take out conditioned filter from Plastic petri-slide filter containers (Filter Cassette). Weigh the preconditioned filter. Record and store it in laboratory coded filter cassette. Follow the same procedure for exposed filter Place the weighed filter into a petri-slide, close tightly, and store at 4°C for at least one year after sampling.

Shipment of Pre-weighed filters

Put the marked pre-weighed filters in Zip pouch. Transport the filters in a dry clean box (temperature control is optional) to the field.

Field sampling

On the Field Data Log, fill in the top portion of the form including: the date/time of visit, the site identification, sampler identification, site name, filter ID number, sample start and stop dates and times, and field operator initials. Perform all necessary pre-sampling procedures as described above. Perform QA/QC checks or maintenance, if required. Record all maintenance activities in the field log book; include time, date, and any concerns that might affect the quality of the sample. Remove the filter to be installed from its protective filter cassette carrier. Fix the filter following manufacturer’s instructions into

place against the bottom of the WINS impactor. Check the system clock and make sure it is within 1 min of NIST time. Strictly follow operator's manual for setting up the sampling programme (24 hours) The Filter Setup Screen shows the start date and time and the end date and time for the next sample. To change the sampling parameters follow the operator's manual. Start Sampling run. Wait until the auto diagnosis for all relevant parameters finishes and the sampler automatically switch over to SAMPLING mode. Check flow (16.7LPM) and Sample volume displays rightly on screen.



Fig.4 Sampling of PM_{2.5}



Fig. 4.1 Before 24 hrs sampling



Fig4.2 After 24 hrs sampling

Recovering the Sample and Data from a Completed Sample Run

From the Main Screen, note the current sampler-operating mode (top line, right side of display). If the sampler is in the WAIT mode or the SAMP (sampling) mode, the sampler has not completed the previously scheduled sampling run. Do not disturb the sampler unless necessary.

If the sampler is in the DONE mode or the ERR mode, press STOP. This allows the sampler to write the final information into storage for the current sample run and must be performed prior to filter exchange. The sampler mode should now indicate STOP.

Open the filter exchange mechanism by pulling straight back on the black handle. The filter holder will lower away from the WINS impactor.

Remove the filter carrier from the filter holder.

Place the filter carrier in the filter cassette case.

From the Main Screen, access to the Filter Data screen following operator's instruction.

Using the information displayed on the Filter Data screen, complete the Field Data Log with the following information from the completed sample run:

- Total Sample Volume – from the Vol. field.
- Average Flow Rate – from the Ave. Flow field.
- Coefficient of Variation – from the %CV field.
- Total Run Time – from the Tot field.
- Maximum Temperature Difference – from the Temp Diff field.
- Minimum, Average and Maximum Ambient Temperatures – from the AmbT fields.
- Minimum, Average and Maximum Filter Temperatures – from the FltT fields.
- Minimum, Average and Maximum Pressures – from the Pres fields.
- If the sampler indicated there was an error, note the error in the field log book and make any repairs as needed. Any fixes should be done prior to the next run date.

U.P. Pollution Control Board
PM 2.5 MONITORING

Station Aligarh

Filter Paper No. PT 0827874

Particulars	Initial	Final
Date	<u>28-4-23</u>	<u>29-4-23</u>
Time	<u>5:54</u>	<u>6:55</u>
Weight	<u>0.198556</u>	<u>0.1932</u>

Total Volume of Air Passed _____ m³

Weather condition Rainy

Dust Contents _____ gms

PM 2.5
MICROGRAM
m³

Fig.4.3 PM_{2.5} sampling form

Calculation and Reporting of Mass Concentrations

The equation to calculate the mass of fine particulate matter collected on a Teflon filter is as below:

$$M_{2.5} = (M_f - M_i) \text{ mg} \times 10^3 \text{ } \mu\text{g}$$

$M_{2.5}$ = total mass of fine particulate collected during sampling period (μg)

M_f = final mass of the conditioned filter after sample collection (mg)

M_i = initial mass of the conditioned filter before sample collection (mg)

10^3 = unit conversion factor for milligrams (mg) to micrograms (μg)

Field records of PM_{2.5} samplers are required to provide measurements of the total volume of ambient air passing through the sampler (V) in cubic meters at the actual temperatures and pressures measured during sampling. Use the following formula if V is not available directly from the sampler:

$$V = Q_{\text{avg}} \times t \times 10^{-3} \text{ m}^3$$

V = total sample value (m^3)

Q_{avg} = average flow rate over the entire duration of the sampling period (L/min)

t = duration of sampling period (min)

10^3 = unit conversion factor for liters (L) into cubic meters (m^3)

The equation given below can be used to determine PM_{2.5} mass concentration:

$$PM_{2.5} = M_{2.5} / V$$

Where,

$PM_{2.5}$ = mass concentration of PM_{2.5} particulates ($\mu\text{g}/\text{m}^3$)

$M_{2.5}$ = total mass of fine particulate collected during sampling period (μg)

V = total volume of air sampled (m^3)

Reporting

Data reporting should be done in prescribed Format. The Format shall contain all information including calibration. The data sheet must be accompanied by Sample Tracking.

FLOW CHART FOR MEASUREMENT OF PM_{2.5}
Check the filter for any physical damages <input type="checkbox"/>
Mark identification number on the filter <input type="checkbox"/>
Condition the filter in conditioning room / desiccator for 24 hours <input type="checkbox"/>
Record initial weight <input type="checkbox"/>
Place the filter on the sampler <input type="checkbox"/>
Run the sampler for eight hours <input type="checkbox"/>
Record the flow rate on hourly basis <input type="checkbox"/>
Remove the filter from the sampler <input type="checkbox"/>
Keep the exposed filter in a proper container <input type="checkbox"/>
Record the total time of sampling & average flow rate <input type="checkbox"/>
Again condition the filter in conditioning room / desiccator for 24 hours <input type="checkbox"/>
Record final weight <input type="checkbox"/>
Calculate the concentration of PM _{2.5} in µg/m ³

Result and Discussion

During the experiment collected data have to discuss.

Data 2023 March & April

Table.1 Showing the data of PM_{2.5} Chandganj (Aliganj) & Talkatora in the month of March 2023

Date	Area	PM _{2.5} (µg/m)	Date	Area	PM _{2.5} (µg/m ³)
02 -03-2023	Chandganj Garden, Lucknow	50.66	03 -03-2023	Talkatora, Lucknow	70.58
06 -03-2023	Chandganj Garden, Lucknow	42.06	07-03-2023	Talkatora, Lucknow	53.74
09 -03-2023	Chandganj Garden, Lucknow	52.2	10-03-2023	Talkatora, Lucknow	48.93
13 -03-2023	Chandganj Garden, Lucknow	55.86	14-03-2023	Talkatora, Lucknow	69.74
16 -03-2023	Chandganj Garden, Lucknow	68.86	17-03-2023	Talkatora, Lucknow	79.82
20 -03-2023	Chandganj Garden, Lucknow	18.29	21-03-2023	Talkatora, Lucknow	58.26
23 -03-2023	Chandganj Garden, Lucknow	31.2	24-03-2023	Talkatora, Lucknow	69.4
27 -03-2023	Chandganj Garden, Lucknow	60.33	28-03-2023	Talkatora, Lucknow	62.53
30 -03-2023	Chandganj Garden, Lucknow	23.06	28-03-2023	Talkatora, Lucknow	83.33
AQI	123	Average=44.724	AQI	150	Average=66.258

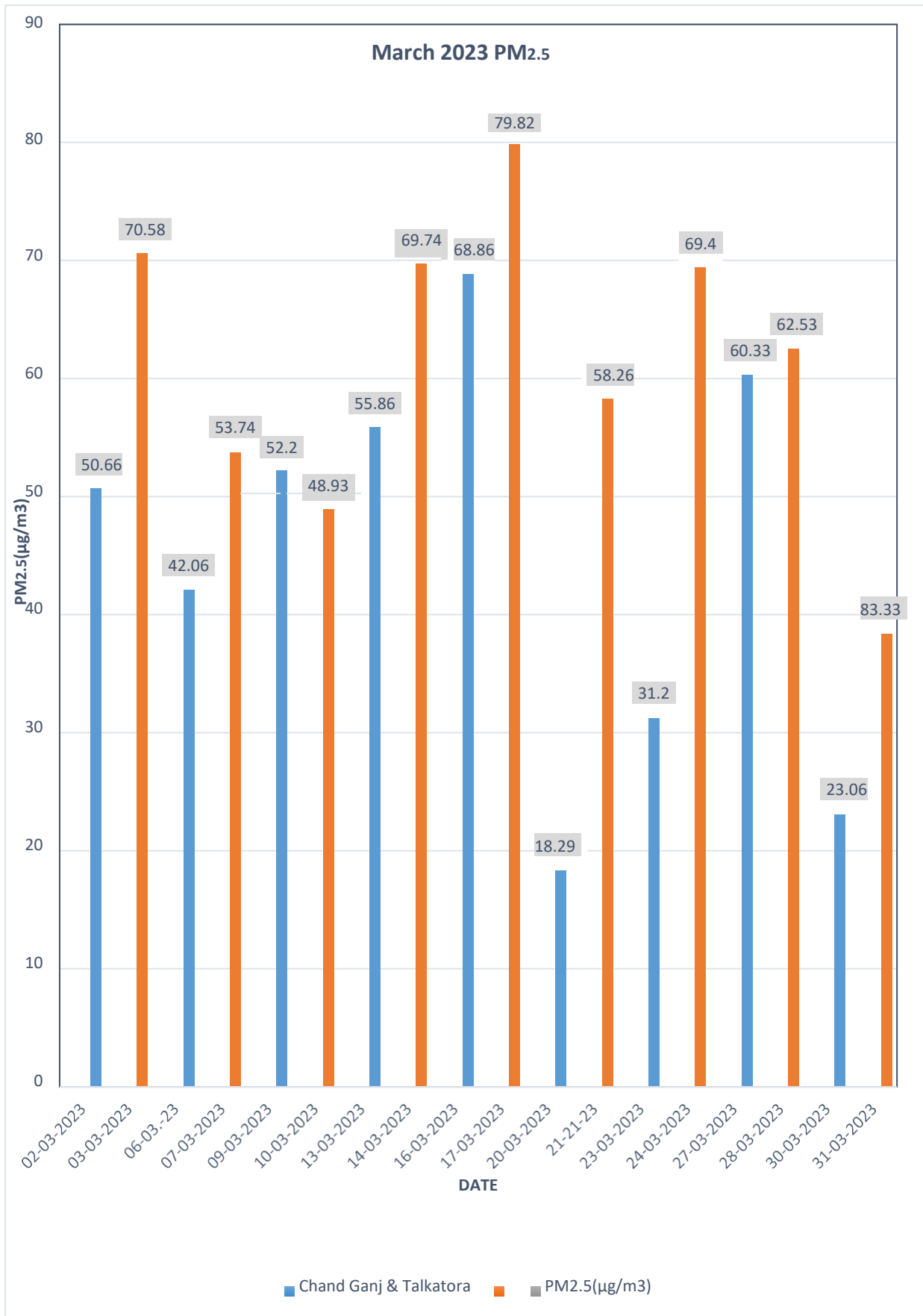


Fig.5.0 Showing the data of March Chandganj(Aliganj) & Talkatora 2023

Table.1.1 Showing the data of PM2.5 Chandganj (aliganj & Talkatora in the month of April 2023

Date	Area	PM2.5($\mu\text{g}/\text{m}^3$)	Date	Area	PM2.5($\mu\text{g}/\text{m}^3$)
03 April 2023	Chandganj Garden, Lucknow	38.21	04 April 2023	Talkatora, Lucknow	71.57
06 April 2023	Chandganj Garden, Lucknow	46.53	07-Apr-23	Talkatora, Lucknow	66.61
10 April 2023	Chandganj Garden, Lucknow	49.86	11-Apr-23	Talkatora, Lucknow	98.11
13 April 2023	Chandganj Garden, Lucknow	51.86	14-Apr-23	Talkatora, Lucknow	89.86
17 April 2023	Chandganj Garden, Lucknow	47.5	18-Apr-23	Talkatora, Lucknow	82.42
20 April 2023	Chandganj Garden, Lucknow	45.86	21-Apr-23	Talkatora, Lucknow	81.33
24 April 2023	Chandganj Garden, Lucknow	41.48	25-Apr-23	Talkatora, Lucknow	59.73
27 April 2023	Chandganj Garden, Lucknow	46	28-Apr-23	Talkatora, Lucknow	81.43
AQI	178	Average=45.912	AQI	177	Average=78.882

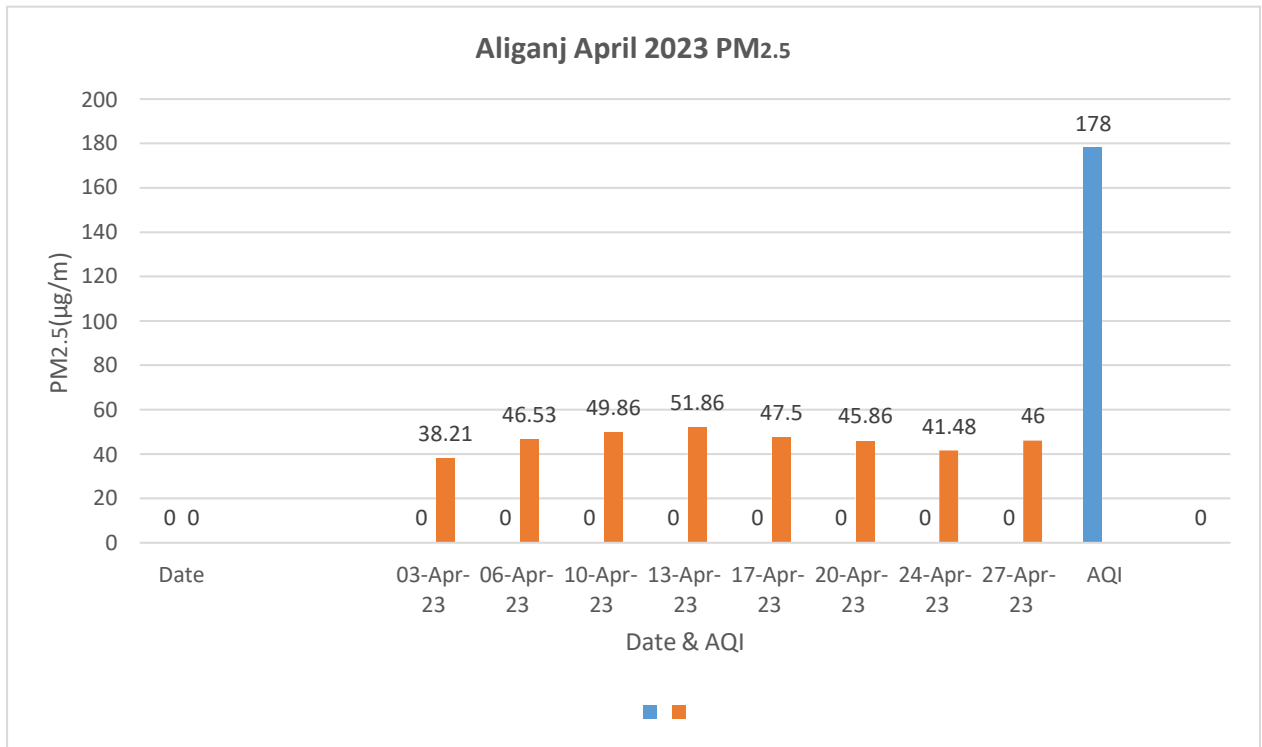


Fig.5.1 showing the data of Aliganj April 2023

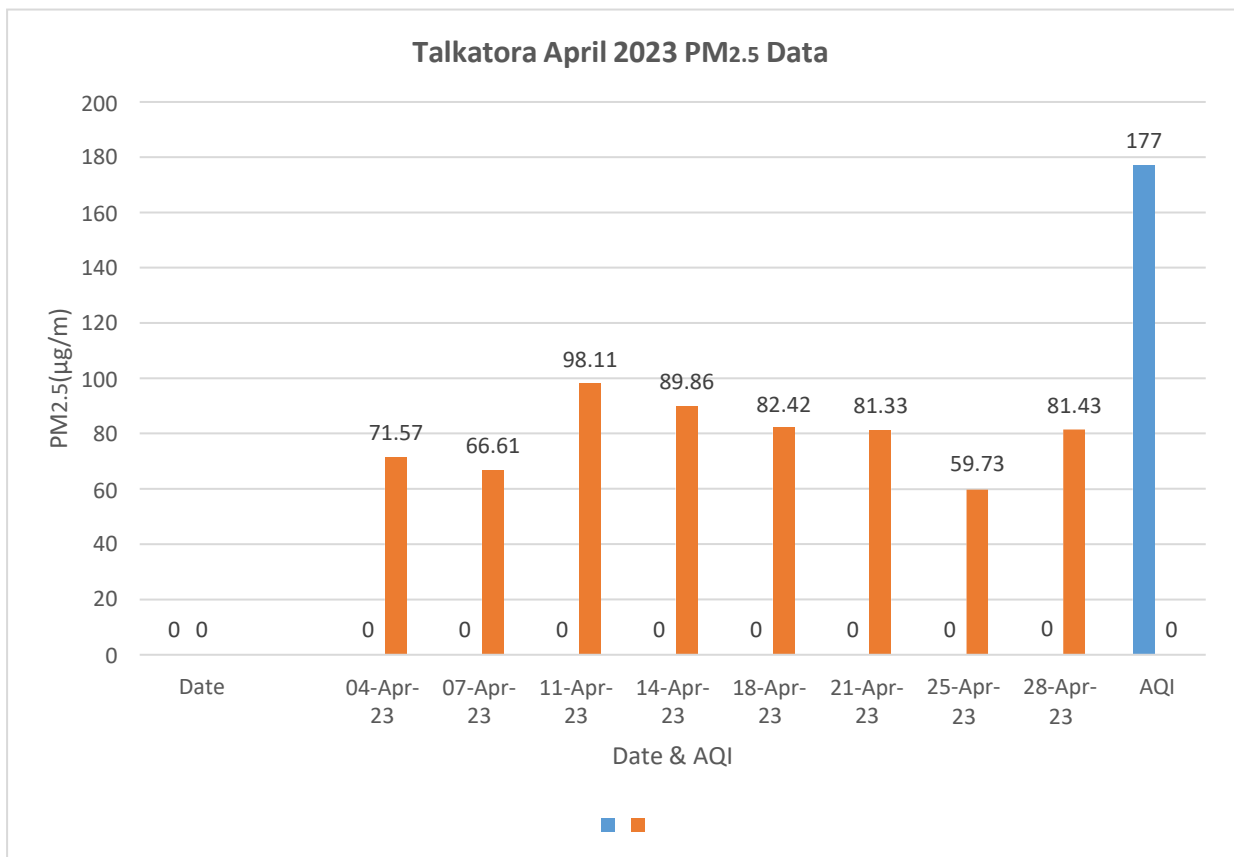


Fig.5.2 showing the data of Talkatora April 2023

Table.1.2 Showing the average Data of SO_x, NO_x & PM₁₀ March						
March Month 2023						
(µg/m ³)						
PM ₁₀		SO ₂		NO ₂		
Yearly	24hrs	Annual	24hrs	Annual	24hrs	
60	100	50	80	40	80	
60	100	20	80	30	80	
S/N	Place	Category	PM ₁₀	SO ₂	NO ₂	AQI
1	Aliganj	Residential	134.39	7.80	25.40	123
2	Talkatora	Industrial	174.84	12.31	36.62	150
3	Gomati Nagar	Commercial	131.78	9.93	32.57	121

Table.1.3 Showing the April SO_x, NO_x & PM₁₀ months Data of 2023 in Average.						
April Month 2023						
(µg/m ³)						
PM ₁₀		SO ₂		NO ₂		
Yearly	24hrs	Annual	24hrs	Annual	24hrs	
60	100	50	80	40	80	
60	100	20	80	30	80	
S/N	Place	Category	PM ₁₀	SO ₂	NO ₂	AQI
1	Aliganj	Residential	202.70	9.00	30.00	178.00
2	Talkatora	Industrial	215.70	10.40	33.90	177.00
3	Gomati Nagar	Commercial	166.20	8.88	34.41	144.00

Table.1.4 Showing the Data of Aliganj April Month 2023				
March & April 2023 Data of Aliganj				
Date	µg/m ³	µg/m ³	µg/m ³	µg/m ³
	PM ₁₀	SO ₂	NO ₂	AQI
02-03-2023	158.0	10.9	33.8	
09-03-2023	108.1	5.3	17.3	
16-03-2023	204.9	9.8	27.5	123.0
23-03-2023	95.3	4.0	19.0	
30-03-2023	82.5	6.7	23.6	
06-04-2023	125.9	9.1	25.1	
13-04-2023	150.1	8.3	22.0	178.0
20-04-2023	100.1	7.0	19.9	
27-04-2023	111.0	5.2	17.4	
	Avera=126.21	Aver=7.36	Aver=22.844	

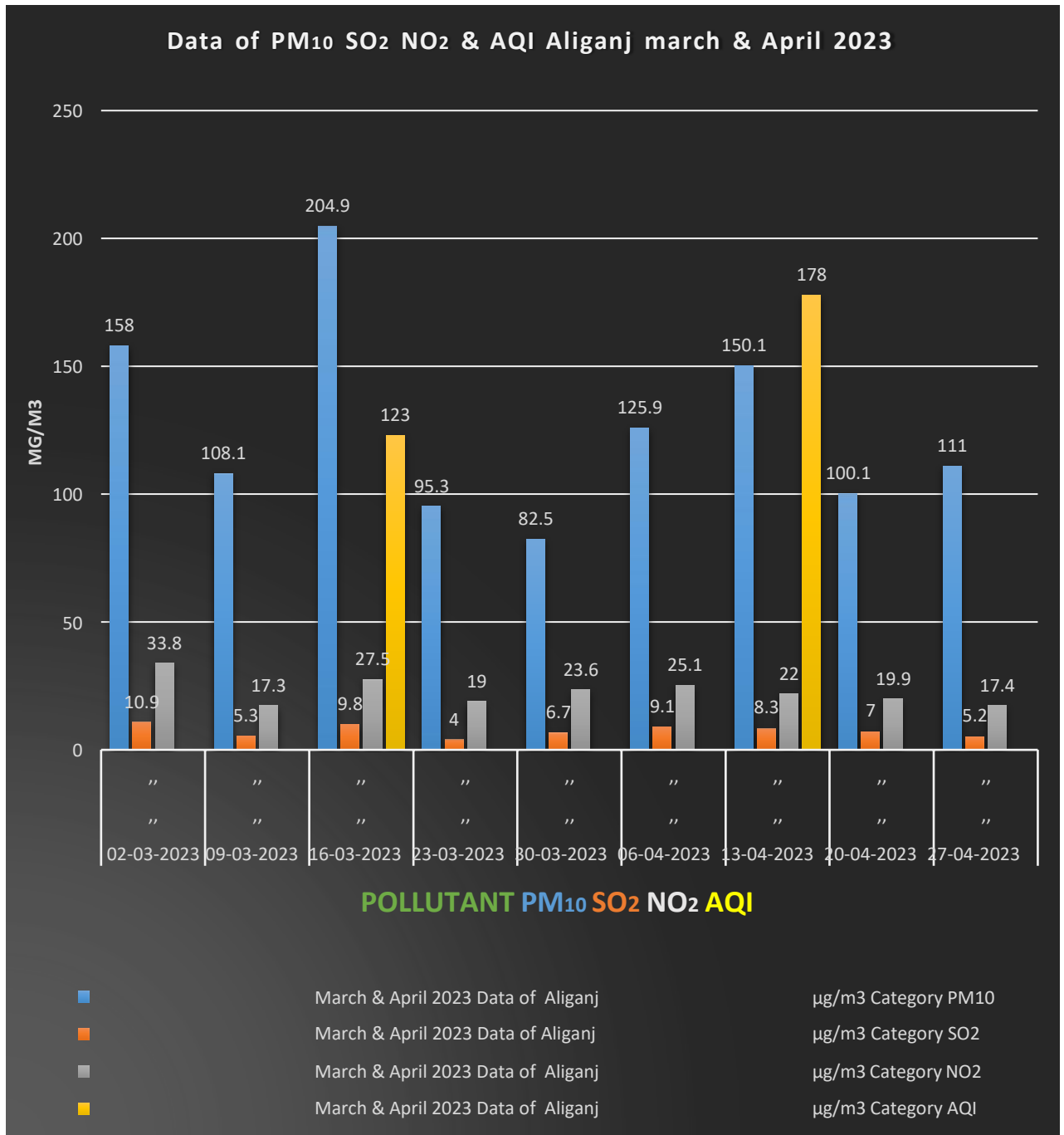


Fig.5.3 showing the Aliganj March & April Data

Table.1.5 showing the month data of Talkatora March & April 2023				
Date		$\mu\text{g}/\text{m}^3$		
	PM10	SO ₂	NO ₂	AQI
03-03-23	267.8	11.0	40.3	
10-03-23	101.7	12.5	38.0	
17-03-23	221.8	13.1	35.2	150
28-03-23	152.0	11.0	38.8	
04-04-23	180.9	10	37.4	
11-04-23	243.7	9.8	36.1	177
21-04-23	171.4	10.9	38.9	
28-04-23	229.7	9.0	35.9	
	Average=196.125	Average=10.912	Average=37.575	

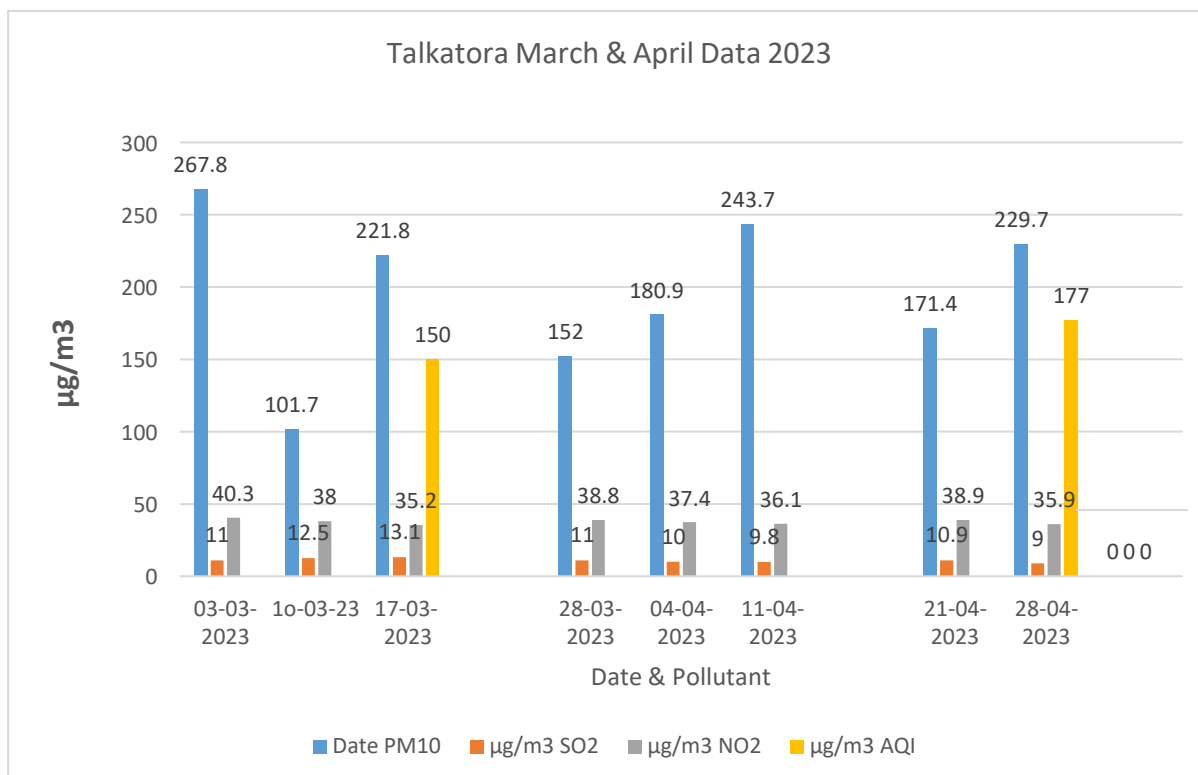


Fig.5.4 Showing the Data of Talkatora April Month 2023

Table.1.6 Showing the Month Data of Gomti Nagar March & April 2023				
Data of Gomti Nagar lkw March & April 2023				
Date	$\mu\text{g}/\text{m}^3$	$\mu\text{g}/\text{m}^3$	$\mu\text{g}/\text{m}^3$	$\mu\text{g}/\text{m}^3$
.	PM10	SO2	NO2	AQI
03-03-23 To 28-03-23	Ave=131.78	Aver =9.93	Aver =32.57	121
01-04-23	164.9	10.5	37.5	
12-04-23	134.0	9.5	36.4	144.0
22-04-23	195.1	8.0	28.1	
29-04-23	109.1	8.6	26.0	
	Average=137.62	Average=9.69	Average=32.39	

Previous Year Data compare

The data was collected during the analysis data have to compare to the data of previous year 2021 – 2022 to 2023 and identify the fluctuation of the level of pollution in the city of the Lucknow.

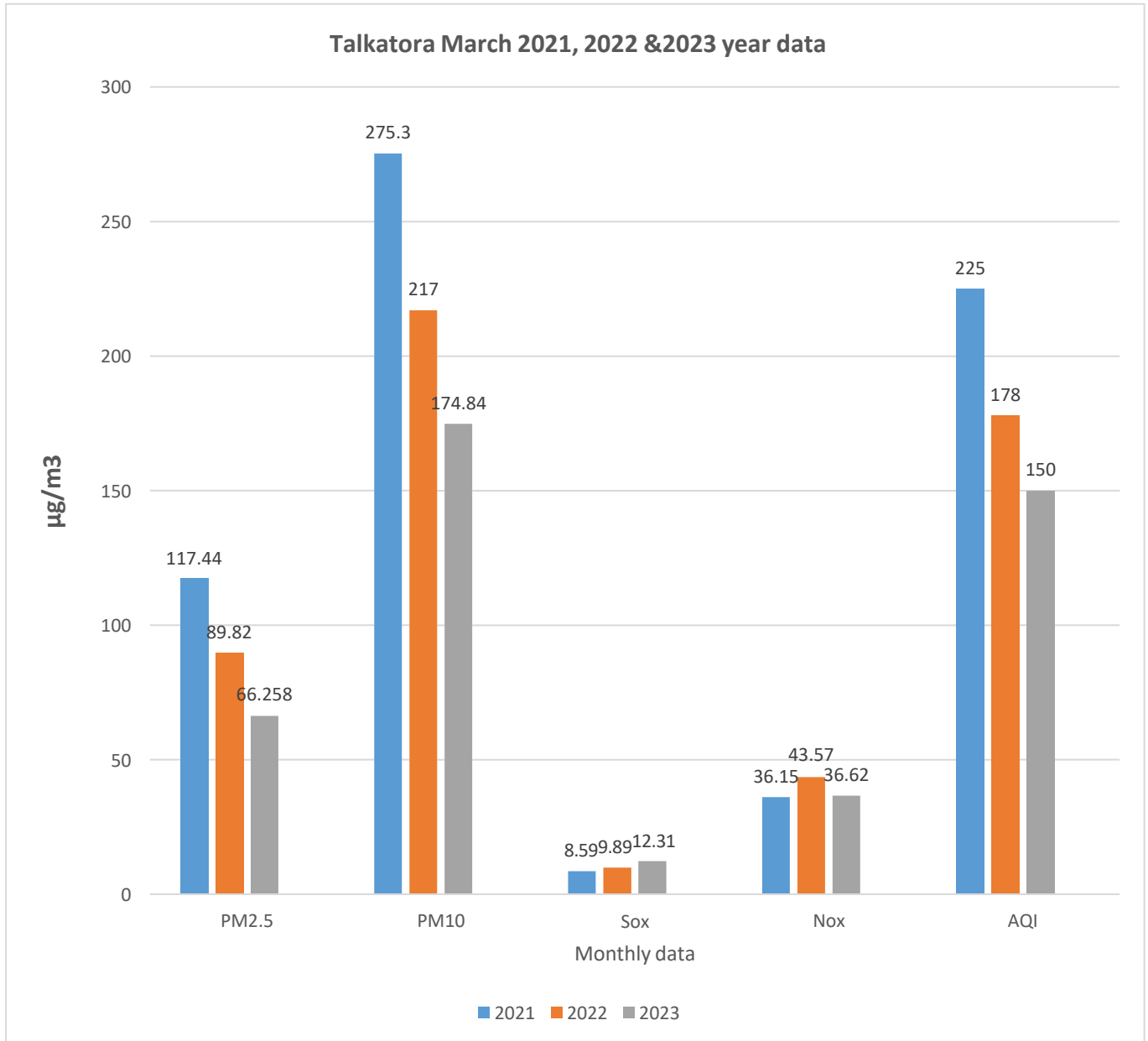


Fig.5.5 Compare the data of last two year March 2021 & 2022 with the 2023 data.

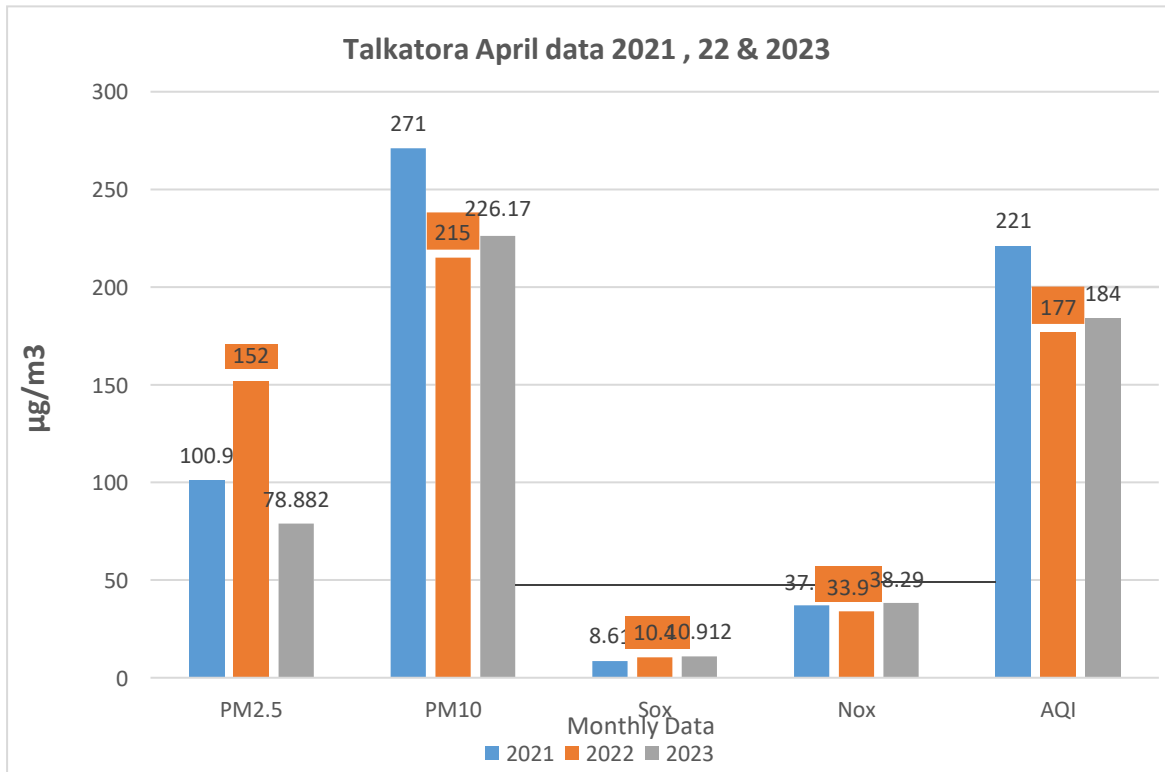


Fig5.6. Compare the data of last two year April 2021 & 2022 with the 2023 Data

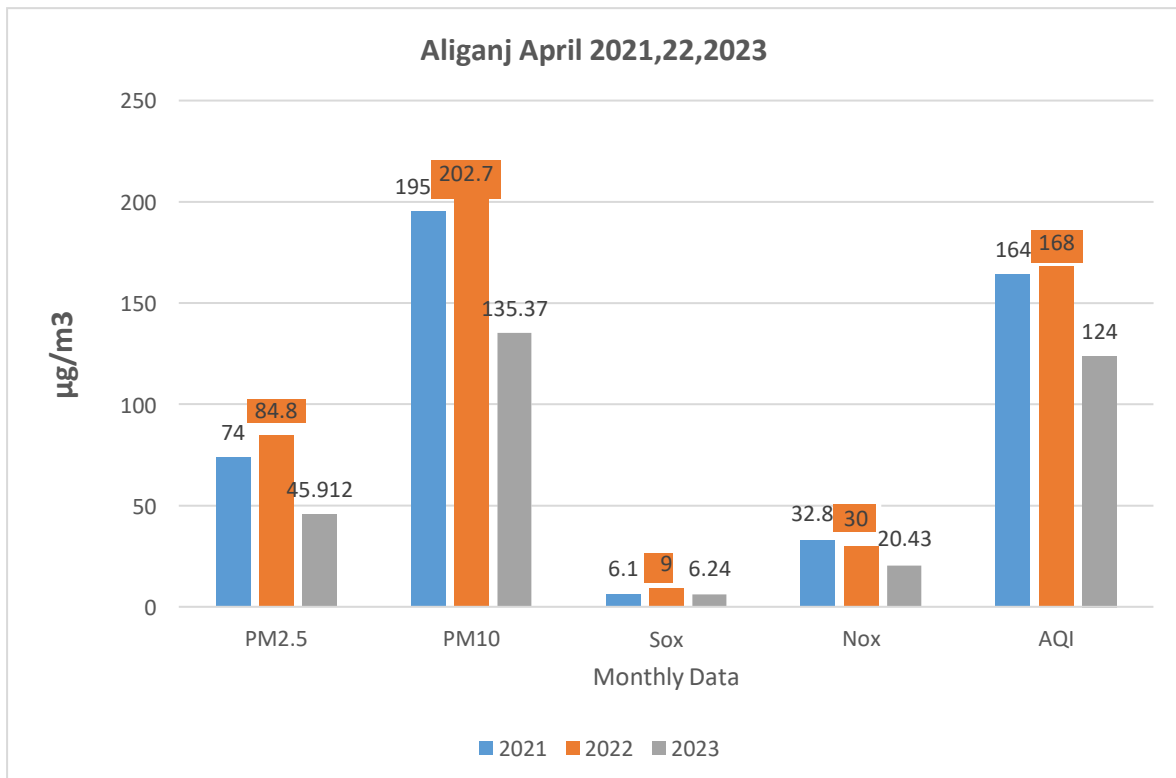


Fig5.7. Compare the data of last two year April 2021 & 2022 with the 2023 Data

Gomti Nagar March 2021, 22&2023

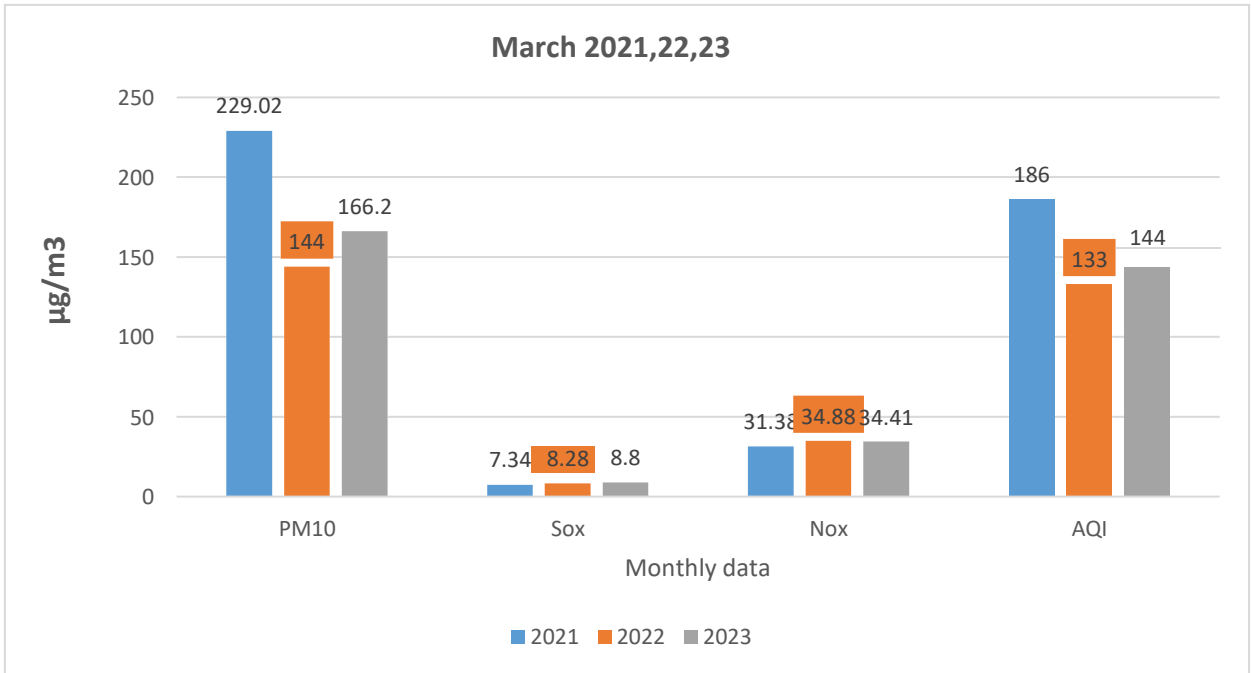


Fig.5.8 Compare the data of last two year March 2021 &2022 with the 2023 Data

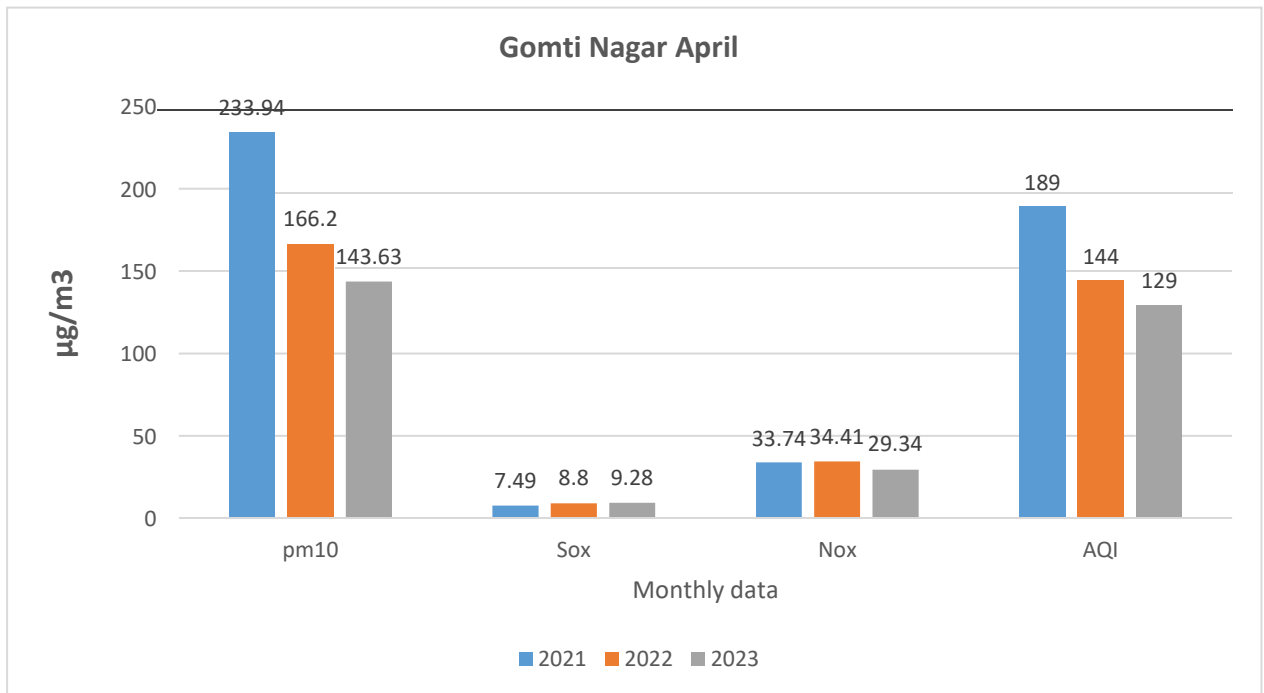


Fig5.9. Compare the data of last two year April 2021 &2022 with the 2023 Data

INDIA level PM₁₀, PM_{2.5} SO_x, NO_x Data

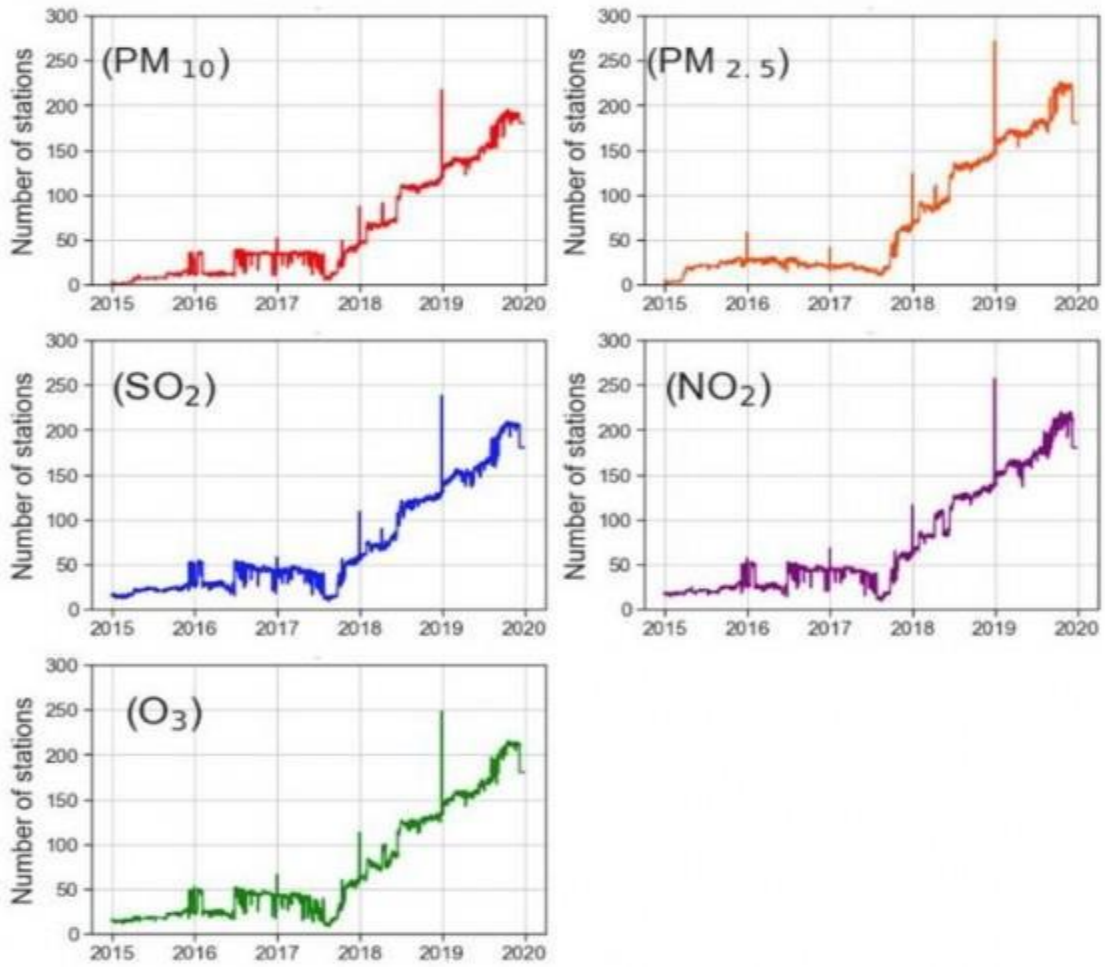


Fig.5.10 Number of CAAQM stations providing valid hourly concentrations across India, between 2015-2019, for PM₁₀, PM_{2.5}, SO₂, NO₂ and O₃, respectively.

CENTRAL POLLUTION CONTROL BOARD'S AIR QUALITY STANDARDS

AIR QUALITY INDEX (AQI)	CATEGORY
0-50	Good
51-100	Satisfactory
101-200	Moderate
201-300	Poor
301-400	Very Poor
401-500	Severe

The March & April 2023 average data shows that is moderate level of pollution in Lucknow City in comparison of 2021 & 2022 average data.

The Lucknow air pollution get increases day by day due to many reasons like urbanization and industrialization .The data of Talkatora always show high AQI in 2021 & 2022 day to day because of huge no. of industry.

Air pollution in Indian cities is an increasing phenomenon. In spite of all the efforts to control pollution by regulatory authorities, the data summarized in the previous section suggest that the air pollution level in Lucknow is on higher side. Particulate matter levels in particular were higher than NAAQS and gaseous pollutants were within the limits. The level of particulate matter observed in Lucknow is in the similar range to that reported from the cities located in northern India. 33 Most of the cities and urban areas located in the northern region of India afflicted with high particulates level. Air pollution level is closely related with meteorological conditions. Lucknow city does not have a uniform weather throughout the year and experiences extreme summers and extreme winters with rainy season from mid-June to mid-September. Lucknow has a complex mix of air pollution like any other urban centres. Huge quantity of fossil fuel is consumed in vehicles, railway engines, industries, generator set, domestic cooking and heating. Burning of petrol, diesel and CNG in vehicles, coal and furnace oil in industry, LPG, kerosene, wood, charcoal etc. for cooking are the major sources of air pollution in city. Traffic congestion due to large number of vehicles on narrow lanes and busy intersections and re-suspension of dust from road gives rise to variety of gaseous and particulate pollution. Industry at Lucknow with obsolete technology coupled with the absence of pollution control measures pollutes industrial areas located in different parts of the city. Festival, marriage, religious celebrations, games, political rallies, processions etc. generate pollution and fireworks also add to this. Activities of building and road construction, dumping and lifting of solid waste from road side open dumps, open burning of dry waste (leaves, rags,

papers, tire, plastic material etc.) The concentration of PM₁₀ found in the air of commercial areas was relatively high as compared to residential and industrial areas. The concentration of air pollutants PM₁₀, SPM, SO₂ and NO_x found in the increasing order of village area (control) <industrial<residential<commercial area. The studies revealed that the area with lower traffic density has shown lower concentration of pollutants than those with higher traffic density. The high traffic density coupled with commercial activities resulted in high pollution levels in commercial areas of Lucknow.

At elevated levels, all the pollutants including metals have adverse effects on human and environmental health. Accumulation of pollutants in the human body through inhalation of air is an important route. The results found in one of the studies in Lucknow showed that 24-h mean respirable particulate (PM_{2.5}, PM₁₀) were higher than the respective NAAQS 24 hourly standards of 60 and 100µg/m³ and may lead to the substantial burden of disease and premature death. Lipmann estimated that the mortality increased by approximately 1% for every 10 µg/m³ increase in PM₁₀ concentration. Following the same assumption the mortality in residential and commercial area of Lucknow was estimated to be about 4.7 and 7.8% respectively.

Concentration of SO₂ and NO_x in Lucknow was under NAAQS-2009 limit (80 µg/m³) However, several studies reported that the gaseous pollutants are related with respirable diseases and reproductive and developmental effect even at low concentration. Changes in biochemical parameters in plant due to exposure to pollutants seems to be suitable marker of air pollution.

In Lucknow SO₂ and NO_x were within the NAAQS limit but was enough to cause injury to plants. In plant leaves highest chlorophyll content was found in monsoon and least in winter. Higher level of pheophytin reduction was found in winter season in various plant species, when the pollution level was high. It was observed that the concentration of the air pollutants at any site correlated with the number and type of vehicles.

CONCLUSION

The level of air pollutants has been found increasing. The data collected so far indicates that the concentration levels of air pollutants increased from well-planned colonies to densely populated areas and were highest along the roadside. At densely populated colonies and roadside colonies, PM_{2.5} & PM₁₀ were found above the permissible limits. High level of PM_{2.5} & PM₁₀ is mainly responsible for unhealthy air quality which can affect the urban people with severe respiratory diseases. Our survey results were also very alarming as diseases like acute respiratory infections such as pneumonia, allergic rhinitis, bronchial asthma, chronic obstructive airway disease (COAD), headache, depression and dizziness were prevalent among the urban dwellers. Awareness through education, advertising and other avenues directed at influencing the behaviour of occupants will play an important role in the near future. Preliminary observations suggest that a higher level of PM_{2.5} & PM₁₀ affects the health of urban people.

The board is not taking a serious step towards the pollution control plan. To make the city cleaner and to provide education among the people is the foremost step that should be taken and the formulation of the strict rules and policies should be done.

Lucknow has witnessed significant growth during the last one and half decades and recorded similar trends of air pollution to other cities located in northern Indo Gangetic plains of India. Most of the time particulate fractions (PM_{2.5}, PM₁₀, and SPM) exceeded the NAAQS limits. Gaseous pollutants Sulphur dioxide and nitrogen dioxide although remained within the NAAQS limits, but were high enough to cause substantial damage to human and plant health. The pollution levels in the city have increased in time and space. High traffic densities and abnormal meteorological factors adversely influenced the ambient air quality of Lucknow. Degraded air quality has adverse effects on building, materials, human health and plants.

Lucknow has witnessed significant growth during the last one and half decades and recorded similar trends of air pollution to other cities located in northern Indo Gangetic plains of India. Lucknow has a complex mix of air pollution like any other urban centers. The present review, based on the studies conducted in Lucknow, identified SO_x, NO_x & particulate matter as the main air pollutant in the city. Most of the time particulate fractions (PM_{2.5}, PM₁₀, and SPM) exceeded the NAAQS limits. Gaseous pollutants Sulphur dioxide (SO_x) and nitrogen dioxide (NO_x) although remained within the NAAQS limits, but were high enough to cause substantial damage to human and plant health.

This is a result of increase of vehicular outflows and gradual escalating private vehicles on street, Rapid urbanization, Industries encompassing the city, Unconsciousness of government and public toward this issue, burning of woods for fuel purposes and burning of the garbage leads to excessive pollution load.

Historical monuments and materials surface get decolorized and degraded due to air pollutants. The reviewed papers suggested that the inhalation of polluted air induces irritation of respiratory tract and may lead to accumulation in human body.

Air pollutants exposure may lead to the substantial burden of disease and premature death. Number and mass concentration, shape, size, composition of particulates and presence of co pollutants determines their detrimental effects. The estimated high values of excess cancer risk for metals associated with PM₁₀ and PM_{2.5} in a study suggest the potential risk to cancer. Fine particulates less than 2.5 micron are the carriers of metals and are loaded with reactive species including PAHs which can pierce the alveoli and diffuse into the blood system, transported to other organs and may cause systemic poisoning.

Two wheelers are the main culprit of the air pollution. It is attributed to the tremendous increase of two wheelers for personal convenience to move to their work place. The second major

sources of air pollution are industrial emission of gaseous pollutants like Sulphur Dioxide. Carbon Monoxide. Ozone and Gaseous Photochemical Oxidants. Nitrogen Oxides. Other sources of air pollution are intensive constructions of the roads, bridges, buildings, quarrying, and digging of roads for telephone cable.

RECOMMENDATION

India needs to generate regular information on the ambient concentration levels of pollutants and take urgent steps to control their emissions. There is an urgent need to adopt suitable strategies for air quality control and to improve urban air quality. Epidemiological studies should be taken up to show how ambient air pollution is affecting people's health and quantify this information in order to provide policy tools for air quality planning. Exposure to air pollutants is largely beyond the control of individuals and requires action by public authorities at the national, regional and local levels.

Lucknow City proposed master plans of 2021 and 2031 have envisaged expansion of the city up to proposed new ring road of about a length of 150 km. The estimated population of city would be about 45 lakhs by 2021. Development in the outskirts of the city will put pressure on its central zone. While there will be a real estate boom on the one hand, there will be a growth in slum conditions on the other.

The increase in transport demand, particularly in central zone, will result in increased air pollution in the city. Environmental aspects are needed to be considered while planning the expansion and development of the city. Sufficient open space in the form of parks, multilane roads able to accommodate the growing traffic load, flyovers on busy crossings, multilevel parking, phasing out of very old vehicles could be some of the steps to stop further deterioration of the cities air quality. Lucknow has witnessed some improvement in this regard. The latest development is the introduction metro rail connecting airport and railway station through north-south and east-west corridor to the different parts of the city. The metro stations will be connected to adjoining areas by local public transport. Availability of swift public transport would reduce personal vehicles on roads and intern air pollution load, due to this major contributor in city pollution.

1. These are some recommendation for improvement of the ambient air quality:
2. Public mass transport must be strengthened to minimize use of personal vehicle.
3. Improvement in the traffic management.
4. Check on fuel adulteration.
5. Regular sweeping of roads to avoid re- suspension of soil dust.
6. Increase use of alternative fuel e.g. CNG
7. Stop cutting of plants and trees.
8. Automobiles must be designed with emission control system.
9. Public awareness.

References

1. IS 5182 Part 2 Method of Measurement of Air Pollution: Sulphur Dioxide?
2. Method 501, Air Sampling and Analysis, 3rd Edition, Lewis publishers Inc. · IS 5182 Part 23 Method of Measurement of Air Pollution: Respirable Suspended Particulate Matter (PM₁₀) cyclonic flow technique · Method IO-2.1 Sampling of Ambient Air for Total Suspended Particulate Matter (SPM) and PM₁₀ Using High Volume (HV) Sampler.
3. CFR Parts 53 and 58 Revised Requirements for Designation of Reference and Equivalent Methods for PM_{2.5} and Ambient Air Quality Surveillance for Particulate Matter; Final Rule 2.0 CARB SOP MLD 055 3.0 Aerosol Science & Technology: The PM 2.5 Federal Reference Method (FRM)." 35(4):339-342 4.0 Federal Register/Vol. 72, No. 112/Tuesday, June 12, 2007/Rules and Regulations.
4. PM_{2.5} Gravimetric Analysis - Revision 7, August 14, 2003, Page 2 of 24 RTI (Research Triangle Institute, US).
5. Method 411, Air Sampling and Analysis, 3rd Edition (Determination of oxidizing substances in the atmosphere).
6. Indophenol method (Method 401, Air Sampling and Analysis, 3rd Edition), Lewis publishers Inc. BIS Method IS 5182 (Part 12):2004 USEPA Method TO-13
7. Method IO-2.1 Sampling of Ambient Air for Total Suspended Particulate Matter (SPM) and PM₁₀ Using High Volume (HV) Sampler · Method 501, Air Sampling and Analysis, 3rd Edition, Lewis publishers Inc. · IS 5182 Part 23 Method of Measurement of Air Pollution :Respirable Suspended Particulate Matter (PM₁₀) cyclonic flow technique · EPA compendium method IO 3 · EPA compendium method IO 3.1 · EPA compendium method IO 3.2 · Standard Method- American Public Health Association (APHA), 20th Edition, 1998.
8. Barman S.C., Kumar N., Singh R., Kisku G.C., Khan A.H.,Kidwai M.M., Murthy R.C., Negi M.P.S.,Pandey P.,Verma A.K.,Jain G. and Bhargava S.K.(2010), Assesment of urban air pollution and it's probable health impact, J. Environ. Biol., 31(6), 913-920.
9. Barman, S.C., Singh R., Negi M.P.S. and Bhargava S.K. (2008), Fine Particles (PM_{2.5}) In Residential Areas of Lucknow City and Factors Influencing the Concentration. Clean Soil Air Water, 36, 111-117.
10. CSIR –IITR Report, Assessment of Ambient Air Quality of Lucknow City during Pre-
 - a. Monsoon, 2018.
11. Fang, G.C., Y.S. Wu, S.H. Huang and J.Y. Rau (2005), Review Of Atmospheric Metallic.
12. Elements in Asia during 2000-2004. Atmos. Environ., 39, 3003-3013.
13. Fisher B (2003), Fuzzy environmental decision-making: applications to air pollution.
14. Atmos Environ 37:1865–1877.
15. Hajek P, Olej V (2009), Air quality indices and their modelling by hierarchical fuzzy.
 - a. Inference systems. WSEAS Trans Environ Dev 5:661–672.

16. http://www.uppcb.com/ambient_quality.htm (Accessed on 31 Dec, 2018).
17. Khillare P. S., Agarwal T., Shridhar V. (2008), Impact Of CNG Implementation on Paks .Concentration in the Ambient Air of Delhi: A Comparative Assessment of Pre- and Post-CNG Scenario, *Environ Monit Assess* 147, 223–233.
18. 19. Kisku G. C, Pradhan S, Khan A.H. Bhargava S.K. (2012), Pollution In Lucknow City And Its Health Implication on Exposed Vendors, Drivers And Traffic Policemen, *Air Qual Atmos Health* (2013) 6:509–515.
19. 20. Li HL, Huang GH, Zou Y (2008), an integrated fuzzy-stochastic modeling approach for Assessing health-impact risk from air pollution. *Stoch Environ Res Risk Assess* 22:789–
20. 803.
21. 21. Mandal T, Gorai AK, Pathak G (2012), Development of fuzzy air quality index using soft Computing approach. *Environ Monit Assess* 184(10):6187–6196.
22. Nolte, C.G., Schauer J.J., Cass G.R. and Simoneit G.R. (2002), Trimethylsilyl Derivatives Of Organic Compounds in Source Samples and In Atmospheric Fine Particulate Matter.
23. *Environ. Sci. Technol.*, 36, 4273-4281.
24. 23. Panday P, Khan A.H., Verma A.K., Singh K.A., Mathur N, Kisku G.C., Barman S.C. (2011),
25. Seasonal Trends of PM_{2.5} and PM₁₀ in Ambient Air and Their Correlation in Ambient Air of Lucknow City, India, *Bull Environ Contam Toxicol* (2012) 88:265–270.