# Assessment of Ambient Air Quality of Lucknow City

## Pre-Monsoon 2022



**CSIR-INDIAN INSTITUTE OF TOXICOLOGY RESEARCH**

VISHVIGYAN BHAWAN, 31, MAHATMA GANDHI MARG, LUCKNOW-226001, U.P., INDIA

विषविज्ञान भवन, 31, महात्मा गाँधी मार्ग लखनऊ-226001, उ.प्र., भारत

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सीएसआईआर-भारतीय विषविज्ञान अनुसंधान संस्थान

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# Salient Features of the Study Area: Lucknow City

- **Geographical Position** : $26^o$ 52' N Latitude
  80$^o$ 56' E Longitude
  128 m above Sea Level

- **Area** : 310 sq. km.

- **Population** : 2815033 as per 2011 Census

- **Projected Population** : 65 lakhs as per Master Plan 2031

- **Climatic condition** : Subtropical climate, cool dry winter (Dec-Feb) & summer (Mar-Jun). Temperature about $45^{°}$C in summer to $3^{°}$C in winter. Average annual rainfall about 100 cm.

- **Total Vehicular number as on 31/03/2022** : 2650286

- **Growth of Vehicles over 2020-2021** : 5.4%

- **Total No. of Fuel Filling Stations (Petrol/Diesel/CNG)** : 159

- **Consumption of Fuel:**
  - **Diesel** : 157220 kL
  - **CNG** : 69295471 kg
  - **Petrol** : 207417.5 kL

- **Major Sources of Pollution** : Automobiles, D.G. Sets
  Biomass burning
  Construction activities
  Dry sweeping and resuspension of road dust

- **Parameters Monitored** : $PM_{10}$, $PM_{2.5}$, $SO_2$, $NO_2$, Pb, Ni and Noise Levels

- **Study Conducted by** : Environmental Monitoring Division CSIR-IITR, Lucknow

## ASSESSMENT OF AMBIENT AIR QUALITY OF LUCKNOW CITY DURING PRE-MONSOON, 2022

### 1.0    SUMMARY

*The Pre-Monsoon ambient air quality assessment of Lucknow city was carried out by the Environmental Monitoring Division of CSIR Indian Institute of Toxicology Research, Lucknow during the months of April-May, 2022. Air quality status was evaluated through monitoring and assessment of some of critical and health affecting air pollutants like 1. **Respirable Suspended Particulate Matter:** $PM_{10}$, cut off size $\leq 10$ μm; and **Fine Particulate Matter:** $PM_{2.5}$, cut off size $\leq 2.5$ μm; 2. **Indicator Gases:** Sulphur dioxide ($SO_2$) and Nitrogen dioxide ($NO_2$); and 3. **Noise levels** at 9 representative locations which are grouped into 3 categories viz., **i. Residential area, ii. Commercial area** and **iii. Industrial area.***

*The 24 hr concentrations of $PM_{10}$ ranged from 118.2 μg/m³ to 203.9 μg/m³ with an average of 157.9 μg/m³ while in case of $PM_{2.5}$, the 24 hr concentrations ranged from 65.0 μg/m³ to 130.1 μg/m³ with an average of 92.8 μg/m³. Irrespective of the locations, the average values of $PM_{10}$ and $PM_{2.5}$ were found to be above the permissible limits of 100 μg/m³ for $PM_{10}$ and 60 μg/m³ for $PM_{2.5}$ prescribed by Central Pollution Control Board, New Delhi. However, the values of $PM_{10}$ and $PM_{2.5}$ increased by 24.2% and 43.9 % compared to the levels measured during Pre-Monsoon 2021. Trace metals of particulate matter (i.e. Pb and Ni) in the city are found in the range 5.45-15.16 ng/m³, avg.10.60 ng/m³ for Pb and 0.86-3.54 ng/m³, avg. 2.22 ng/m³ for Ni.*

*The 24 hr concentrations of $SO_2$ ranged from 9.6 to 22.2 μg/m³ with an average of 14.1 μg/m³ while the 24 hr concentrations of $NO_2$ ranged from 28.4 to 41.6 μg/m³ with an average of 35.7 μg/m³. The values of $SO_2$ and $NO_2$ increased by 5.02 % and 12.2 %, respectively. However, the average values of $SO_2$ and $NO_2$ were well below the permissible limits of 80 μg/m³ for both $SO_2$ and $NO_2$ prescribed by CPCB, New Delhi (NAAQS-2009).*

*The day time and night time noise levels ranged from 63.8 to 73.2 dB(A) and 60.8 to 67.8 dB(A) in residential areas and from 79.7 to 86.6 dB(A) and 67.5 to 75.9 dB(A) in commercial areas respectively. These measured values were above their respective day time standard of 55 dB(A) and night time standard of 45 dB(A) for residential areas and 65 dB(A) and 55 dB(A) for commercial areas respectively as per NAAQS. At Amausi Industrial area, the day time and night time noise levels were 81.3 dB(A) and 72.9 dB(A) respectively. The values are below the national standard of 75 dB(A) for day time and 70 dB(A) for night time recommended for Industrial areas.*

*The present study reveals that the levels of pollutants like inhalable particulate matter, gases, and noise are gradually increasing due to the fact that air quality monitoring of Pre-Monsoon 2022 affects the complete unlock from the COVID restrictions. Further increase of population and subsequent demands for food, transportation, livelihood and living spaces has a predominant role in escalating the levels of ambient air pollutants in the city. Vehicles plying on the road, domestic cooking, baking/firing in hotels, near field crop combustion, emissions from generators and industries are also contributory factors towards urban emissions. The present study reveals that the air pollution is substantially increased in Lucknow city for pre-monsoon 2022. Mainly for the reason that 5.4% growth of vehicles plying on road and proportionately increased fuel consumption.*

## 1.1    INTRODUCTION

The word "Environment" is derived from French word "Environer" which means surroundings and is considered as a complete condition in which all organisms live. This consists of air, water, and food, and sunlight which are the basic requirements of all living beings to carry on their life functions. Mainly four environment components, are not only interconnected and interlinked but also reacts with each other and respond accordingly. If one particular component is disturbed because of natural or anthropogenic activities then the whole balance of the other three components will be upset. At present, these environmental components are greatly disturbed because of human interference and rapid developments which accelerate the change of nature and many catastrophic phenomena are occurring worldwide.

The four key components being referred to are:

i. **Atmosphere -** the cover of air that envelopes the earth's surface. It is the protective thick gases, surrounding the earth, which sustains life on earth and saves it from the unfriendly environment of outer space. It extends to a height of about 1600 km from the earth's surface.

ii. **Hydrosphere -** covers more than 75% of the earth's surface either as oceans (salt water) or as fresh water. The hydrosphere includes sea, rivers, oceans, lakes, ponds, streams etc.

iii. **Lithosphere -** the solid component of the earth is called the lithosphere, which mainly includes soil, earth, rocks, mountains etc.

iv. **Biosphere -** the planet earth along with all its living organisms including human beings and the environment (air, land, and water) sustains life. It indicates the domain of living organisms and their interactions with the environment of other components i.e. the atmosphere, hydrosphere and lithosphere.

Greater the population greater the demand for housing, vehicles, electricity, and road infrastructure and this proportionately increases the demand for food/fuel, and educational/hospital /recreational facilities. Fossil fuel consumption is likely to increase. When a vehicle burns fuel, it directly emits heat energy, $CO_2$ and other obnoxious pollutants either in solid or gas/liquid (burned engine oil) form which are harmful to human beings. Greenhouse gases $CO_2$ and $NO_2$ produced during fuel burning may absorbs heat energy indirectly and the cause for local or global warming.

Deterioration of overall air quality leads to climate change, global warming and ice melting which are likely to reduce the gross agricultural productivity, deforestation, and lifestyle of public. A surge in temperature was recorded in Lucknow from mid-March 2022. There are two possibilities, for this 1st one- after Covid period all the industries/businesses are in full operation as before the pandemic. 2nd cause may be the ultraviolet rays which are shorter in wavelength with a higher amount of energy. As the $O_3$ layer is also thinning at the level of the Stratosphere, owing to the various chemicals released into the atmosphere, there are fair chances of penetration of Ultra Violet rays which strike the earth's surface and release heat energy.

### 1.1.1 Layout of Lucknow City

Lucknow is the capital and the largest city of the Indian state of Uttar Pradesh and the city's area and urban population are growing at a very rapid pace. The present population is anticipated to touch 35 lakhs. Lucknow is the eleventh most populous city and the twelfth-most populous urban agglomeration of India. Bounded on the east by Barabanki, on the west by Unnao, on the south by Raebareli and in the north by Sitapur and Hardoi, Lucknow sits on the northwestern shore of the Gomti. Gomti river flows across the city and divides it into 2 parts viz Cis and Trans Gomti. The city stands at an elevation of 123 meters (404 ft) above sea level. Lucknow city had an area of 402 $km^2$ till December 2019, when 88 villages were added to the municipal limits and the area increased to 631 $km^2$. Lucknow has always been a multicultural city that flourished as a North Indian cultural and artistic hub and the seat of power of Nawabs in the 18th and 19th centuries. It continues to be an important center of governance, administration, education, commerce, aerospace, finance, pharmaceuticals, technology, design, culture, tourism, music and poetry.

### 1.1.2 Vehicular Inventory and Fuel Consumption in the City

Vehicular and fuel consumption inventory for Lucknow city were carried out and primary information collected from RTO as on March 31, 2022 (Table 1), which showed an increase of registered vehicle number by 5.4 % in the city from last year 2020-21. The total number of CNG & electricity buses of UPSRTC operational is 69

& 97 respectively by 2022 (Table 2 & 3). Different oil and gas companies have provided total number of fuel outlets (i.e. petrol, diesel & CNG) in Lucknow are 159 (Table 4). Consumption of fuel between years 2021 and 2022 is presented in Table 5, and it is found that the consumption of petrol and CNG increased by 4.43% and 157.98 % respectively while diesel and LPG consumption were decreased by 11% and 3.1% respectively by 2021-22. CNG vehicle number of city is represented in Table 6.

### 1.1.3 Study Rationale

Air pollution has become a major challenge in Lucknow due to the multiplicity and complexity of sources. Despite the implementation of stringent abatement measures by regulatory agencies, Lucknow city has faced several air pollution problems, particularly with particulate matter of unknown sources. The city has increased traffic signals to control vehicle movements. However, the idle mode of vehicles, as well as traffic jams at multiple signals, has affected the air quality, particularly near traffic junctions by adding an additional amount of emission load by jammed vehicles. Further, urban population and economic demands increased open cooking and street food stall activities, which intake has increased the cooking combustion-related emission load to ambient air. The complexity of the source compounds has increased the difficulty of determining the predominant source of airborne particle pollution. The problem is often compounded by the predominance of widely distributed area (fugitive) sources in the city, and also the lack of understanding of the sources of secondary aerosol, their formation, and transport.

In different areas of Lucknow, old buildings are demolished and also excavation takes place for new foundations/construction and this becomes a major source of dust. The unpaved and damaged roads are also the sources of soil and road dusts. Although the State Govt. has taken many initiatives like cleaning programs under the Swachha Bharat Programmes, and yet many off side localities/areas of the city have huge garbage and waste dumps, which are also a source of air pollution. Unused or phased-out vehicles lying on the road side also add to the sources of pollution. Therefore, the fugitive sources along the road sides are the major cause for the pollution.

Therefore, it is extremely important to be aware of the latest status of air pollution in the city to understand the sources and receptor linkages and implement cost-effective strategies for emission reduction. To address air pollution of Lucknow city, CSIR-IITR has been conducting air quality surveys at 9-locations across Lucknow city since 1997 and regularly identifying the sources, developing their inventory of emissions and generating air pollution data for public awareness and to support in government policy making. Pre-monsoon 2022 (April to May, 2022) air quality survey at 9 locations in Lucknow covering industrial, residential and commercial areas has been carried out with respect to $PM_{10}$, $PM_{2.5}$ $SO_2$, $NO_2$, trace metals (Pb and Ni), and noise pollution and this report illustrate the results with a scientific discussion and recommendations.

### 1.1.4 Objectives

The following objectives are delineated for the pre-monsoon 2022 study:

❖ *To study the air quality status of pre-monsoon season at different locations*
❖ *To ascertain the concentration of $PM_{10}$, $PM_{2.5}$, $SO_2$, $NO_2$, and trace metals (Pb and Ni) associated with $PM_{10}$.*
❖ *To study the trend of air pollution in Lucknow city over the years.*
❖ *To find out the day and night-time noise levels of the current season at different locations*
❖ *To provide awareness on the current air pollution index*
❖ *To develop the scientific database and recommendations to assist regulatory agencies in remedial measures for the city*

## Table 1: Comparison of Vehicle Numbers in Lucknow

| S. No. | Type of Vehicles | No. of Registered Vehicles as on 31st March | | Increase in % |
|---|---|---|---|---|
| | | **2021-22** | **2020-21** | |
| 1. | Multi Articulated | 7537 | 6648 | 13.4 |
| 2. | Light, Medium & Heavy Weight Vehicles (Four Wheelers) | 56908 | 51603 | 10.3 |
| 3. | Light Commercial Vehicles (Three Wheeler) | 3921 | 3798 | 3.2 |
| 4. | Buses | 4794 | 4383 | 9.3 |
| 5. | Omni Buses | 547 | 489 | 11.9 |
| 6. | Taxi | 51165 | 37993 | 34.7 |
| 7. | Light Motor Vehicles (Passenger) | 11139 | 10557 | 5.5 |
| 8. | Two Wheelers | 1931469 | 1860778 | 3.7 |
| 9. | Motor Cycle on Hire | 409 | 384 | 6.5 |
| 10. | Car | 353100 | 330596 | 6.8 |
| 11. | Jeep | 126222 | 105707 | 19.4 |
| 12. | Tractors | 29169 | 28022 | 4.1 |
| 13. | Trailers | 2103 | 1989 | 5.7 |
| 14. | Others | 71803 | 71514 | 0.1 |
| **Increase in total number of vehicles** | | **2650286** | **2514461** | **5.4** |

*Source: RTO, Lucknow, 2022*

**Table 2: Details of Lucknow CNG City Bus Service (Gomti Nagar Depot), 2022**

| S. No. | Route No. | To and Fro | No. of Buses | Frequency (minutes) |
|---|---|---|---|---|
| 1 | 101 | Goyal institute-Ramswaroop college  BBD- Dayal Regidency- Matiyai tiraha-Petrol Pump- Chinhat turn-kathota chauraha- Amity Univrsity-Honeyman Chauraha- Judicial Training Research Institute-Husadiya Chauraha-Malik timber-Ptrkar puram-Manoj pandey Chauraha-Shankar Chauraha- Dayal Adda MM Malviya Turn-Tikuniya Park-Daynik Jagran- Sikandarbagh- Jawahar Bhawan-Shakti bhawan -Incometax Office- GPO-Bapu bhawan-Barlington- Hussainganj-Vikasdeep- KKC- Charbagh-Charbagh Bus station. | 9 | 09 |
| 2 | 103 | Charbagh-KKC-Vikasdeep-  Hussainganj-  Barlington-Bapu Bhawan- GPO- Incometax office-Shakti bhawan- Jawahar Bhawan- Sikandarbagh- Gokhle Marg- Papermill Colony- Nishatganj- Gol Market- Badhshah nagar- Shaktinagar Dhaal- Lekhraj- Neelgiri- Bhootnath- HAL- Aravali turn- Polytechnic- New High coart- Kamta- Chinhat- Matiyari Chauraha- Shivpuri- TATA Motors-  Chakkar Chauraha- Sharda Nahar- Samarpan Hospital- | 9 | 09 |
| 3 | 202 | Industrial area- Scooter India-Gauri vihar- Hydle Colony- Sainik School- Shanti Nagar- Nadarganj  - Airport Bagiya No. 3- Bagiya No. 2- Transport Nagar- Aurangbad- Ramabai Maidan- Shubham South City- Uttarethiya- Vrindavan Yojna- Awadh Shilp Gram- Delhi Public School- Awadh Shilp Gram-2. - CMS- Ahimamau- Suda Office- Cricket Stadium- Delhi Public School- Homegaurd Office- Husadiya- Gomtinagar Bus Station- High Coart -Kamta. | 34 | 03 |
| 4 | 401 | Integral University- P.S. Gudamba- Pahadpur Tiraha- Gayatri Mandir- Tedhi Puliya- Chandra sweet house- Lohiya Nagar Turn- Lekharaj Panna- PNB Turn- K. K Palace- Vikasnagar- Rahim Nagar- wireless Chauraha- Mahanagar  Bayaz- Gol market- Badshahnagar- Nishatganj- Paper mill Colony- Gokhley Marg Sikandarbag- Jawahar Bhawan- Shakti Bhawan- Income tax office- GPO- Bapu Bhawan- Barlingtn- Hussainganj- Vikasdeep- KKC- Charbagh  - Mavaiya- Alambagh- P.S. -Tedhi puliya- Alambagh Bus station- Ajanta hospital- Alambagh Chauraha- Ramnagar- Pooran Nagar- Singarnagar- Awadh Hospital- Devpur Para- Para Mod- Sindhi Colony- Hanskheda- Kashiram Yojna. | 5 | 16 |

| S. No. | Route No. | To and Fro | | |
|---|---|---|---|---|
| 5 | 402 | Integral University- P.S. Gudamba- Pahadpur Tiraha- Gayatri Mandir- Tedhi Puliya- Chandra sweet house- Lohiya Nagar Turn- Lekharaj Panna- PNB Turn- K. K Palace- Vikasnagar- Rahim Nagar- wireless Chauraha- Mahanagar  Bayaz- Gol market- Badshahnagar- Nishatganj- Paper mill Colony- Gokhley Marg Sikandarbag- Jawahar Bhawan- Shakti Bhawan- Income tax office- GPO- Bapu Bhawan- Barlingtn- Hussainganj- Vikasdeep- KKC- Charbagh  - Mavaiya- Alambagh- P.S. -Tedhi puliya- Alambagh Bus station- Ajanta hospital- Alambagh Chauraha- Ramnagar- Pooran Nagar- Singarnagar- Awadh Hospital- Barabirwa- Burgawan-BSNL Trainng Insitute- Prem Plaza- Ashiyana Chauraha- P.S Ashiyana- Qilagaon Chauraha - Qila Chauraha-  Rajnikhand Turn- Rajnikhand. | 12 | 12 |
| | | **Total** | 69 | |

## Table 3: Details of Lucknow Electric City Bus Service (Dubagga Depot), 2022

| S. No. | Route No. | To  and Fro | No. of Buses |
|---|---|---|---|
| 1 | 105 | Raja ji Puram – Charbagh –  Nishatganj – Polytechnic – kamta- Chinhat-Awadh Bus Station (Kamta) – BBD | 14 |
| 2 | 301 | Scooter India – Krishna Nagar – Awadh Hospital – Alambagh – Mawaiyya – Charbagh – GPO –Engg. College | 22 |
| 3 | 502 | Scooter India-Awadh Hospital-Alambagh- Charbagh- GPO – Sikanderbagh chauraha-Polytechnic- Awadh Bus Station (Kamta) – Goyal Ins. | 5 |
| 4 | 801 | Balaganj  -  Dubagga – Bhitauli– New High Coart-Polytechnic  – Virajkhand | 16 |
| 5 | 801-E | Balaganj  -  Dubagga – Bhitauli — Polytechnic –  Virajkhand Bus Station | 8 |
| 6 | 1102-E | Ghantaghar- Chawk-Dubagga-Sitapur Bipass-Kasmandi-Navipanah-mall. | 12 |
| 7 | 1201-E | Dubagga Dipo- Sitapur Bipass- Career Dental College. Dental College – Dubagga- Awadh Hospital – SGPGI- Mohanlalganj. | 20 |
| | | **TOTAL** | 97 |

## Table 4: Fuel Outlets in Lucknow City

| S.No. | Agency | Number of outlets as on 31st March 2022 |
|---|---|---|
| 1 | Indian Oil Corporation (IOC) | 55 |
| 2 | Bharat Petroleum Corporation Ltd. (BPCL) | 30 |
| 3 | Hindustan Petroleum Corporation Ltd. (HPCL) | 42 |
| 4 | Compressed Natural Gas Stations (CNG) | 32 |
| Total | | 159 |

*Source: Indian Oil Corporation (IOC), Lucknow; Bharat Petroleum Corporation (BPCL); Hindustan Petroleum Corporation (HPCL); Green Gas Limited, Lucknow, 2022.*

## Table 5: Fuel Consumption in Lucknow City

| S. No. | Agency | Petrol in kL | | | High Speed Diesel in kL | | | CNG in Kg | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Apr. 21 to Mar. 22 | Apr. 20 to Mar. 21 | % Change | Apr. 21 to Mar. 22 | Apr. 20 to Mar. 21 | % Change | Apr. 21 to Mar. 22 | Apr. 20 to Mar. 21 | % Change |
| 1. | IOC | 98433 | 85316 | 15 | 71027 | 66726 | 6.44 | 20313039 | 11563212 | 75.66 |
| 2. | BPCL | 64139 | 48883 | 31.20 | 42769 | 33984 | 25.85 | 90000 | 918151 | -90.19 |
| 3. | HPCL | 44845.5 | 56950 | -26.99 | 43424 | 75950 | -25.85 | 3075300 | 1840921 | 67.05 |
| 4. | Green Gas | - | - | - | - | - | - | 40395998 | 12538366 | 222.12 |
| Total | | 207417.5 | 198607 | 4.43 | 157220 | 176660 | -11 | 69295471 | 26860650 | 157.98 |
| | | LPG in Ton | | | | | | | | |
| 5. | IOC | Apr. 21 to Mar. 22 | Apr. 20 to Mar. 21 | % Change | - | - | - | - | - | - |
| | | 1007 | 1040 | -3.1 | - | - | - | - | - | - |

Source: Indian Oil Corporation (IOC), Lucknow; Bharat Petroleum Corporation (BPCL);
Hindustan Petroleum Corporation (HPCL); Green Gas Limited, Lucknow, 2022.

**Table 6: Distribution of CNG Vehicles**

| S. No. | Vehicles | Number | | % of Change |
| --- | --- | --- | --- | --- |
| | | 2021-22 | 2020-21 | |
| 1 | Auto Rickshaws | 4343 | 4343 | - |
| 2 | Tempo Taxi | 2575 | 2575 | - |
| 3 | Buses (UPSRTC) | 260 | 260 | - |
| 4 | Buses (Private) | 40 | 40 | - |
| 5 | School Buses | 1745 | 1557 | 12.07 |
| 6 | School Van | 3117 | 2231 | 39.71 |
| 7 | Private Vehicles | 472 | 472 | - |
| 8 | Private Cars | 30015 | 24539 | 22.31 |
| | **Total** | **42567** | **36017** | **18.18** |

*Source: RTO, Lucknow; Green Gas Limited, Lucknow, 2022.*

## 1.2 METEOROLOGICAL CONDITIONS

Meteorology plays a major role in dispersion and dilution of air pollution. Meteorological condition during the study period (i.e. April- May 2022) has been observed in Lucknow city and illustrated in Figure 1. Relative humidity is in the span of 25-75%, whereas temperatures are ranged between 24-34° C. Slight rainfall was observed between 23rd to 25th May 2022, with maximum precipitation being 0.4 mm during the study period. Windrose shows that the predominant wind direction is from East followed by East South East. Calm winds are observed about 2-3% of the times and maximum wind speed is upto 4-5 m/s.
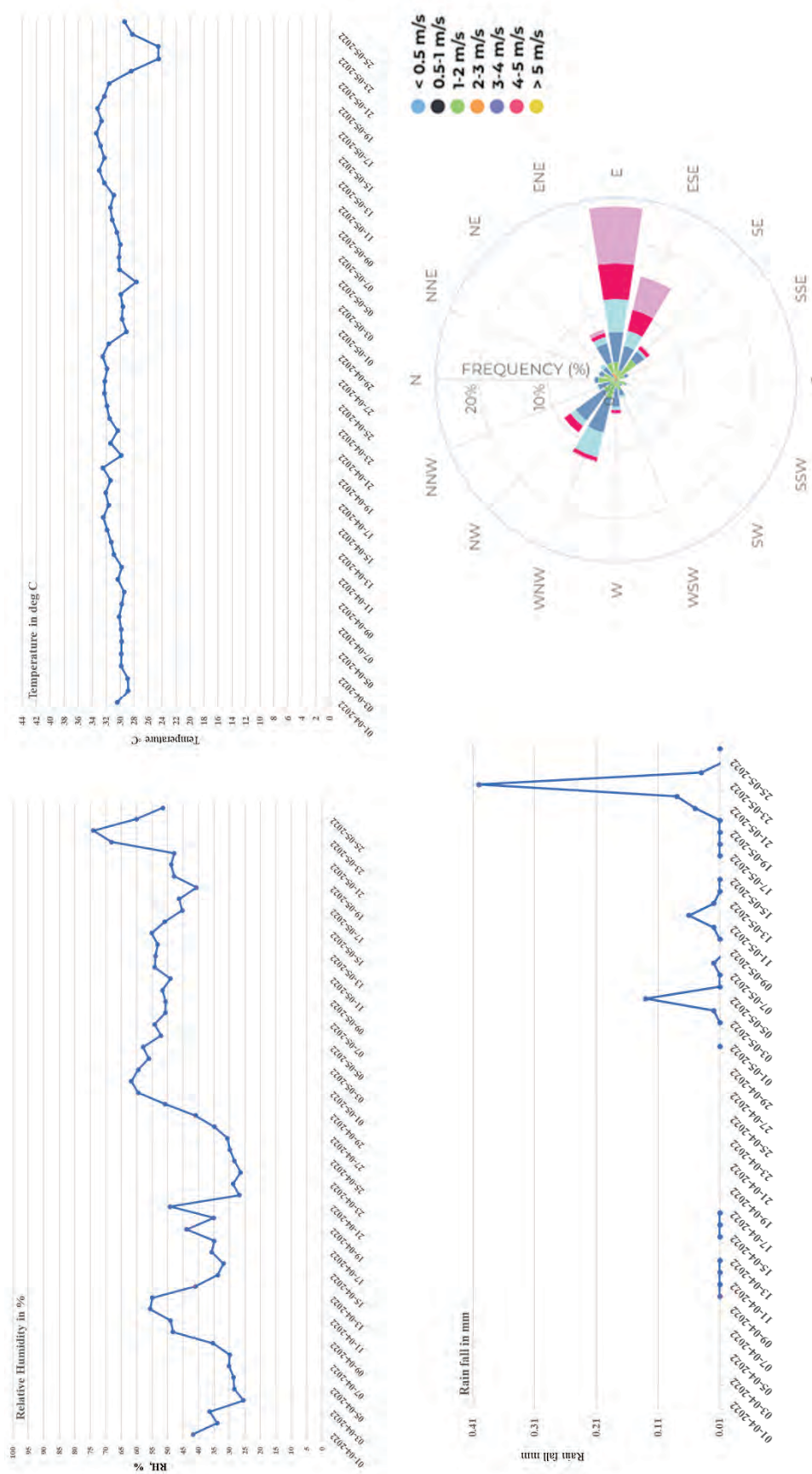
**Figure 1: Meteorological conditions during the survey period in Lucknow city**

### 1.3    MONITORING LOCATIONS AND METHODOLOGY

Nine air quality monitoring locations representing different activities/ areas i.e., four in residential, four in commercial cum traffic and one industrial area were selected for the Pre-Monsoon 2022 study as summarized in Table 7 and Figure 2 and adopted methodologies are given in Table 8. A total of eight samplings were carried out during the months of April-May, 2022.

**Table 7: Monitoring Locations**

| S .No. | Locations | Activities |
|--------|-----------|------------|
| 1 | Aliganj | Residential |
| 2 | Vikas Nagar | Residential |
| 3 | Indira Nagar | Residential |
| 4 | Gomti Nagar | Residential |
| 5 | Charbagh | Commercial cum traffic |
| 6 | Alambagh | Commercial cum traffic |
| 7 | Aminabad | Commercial cum traffic |
| 8 | Chowk | Commercial cum traffic |
| 9 | Amausi | Industrial |

**Table 8: Parameters and Methodology for Air Quality Monitoring**

| Sl. No. | Parameters | Time Weighted Average | Methods of Measurement |
|---------|-----------|----------------------|------------------------|
| 1 | Particulate Matter ($PM_{10}$) | 24 hours | Gravimetric |
| 2 | Fine Particles ($PM_{2.5}$) | 24 hours | Gravimetric |
| 3 | Sulphur dioxide ($SO_2$) | 24 hours | Improved West Gaeke |
| 4 | Nitrogen Dioxide ($NO_2$) | 24 hours | Modified Jacob & Hochhesier (Na-Arsenite) |
| 5 | Noise Level | 1 hour | The measurement of noise level was carried out during the day (6 AM to 10 PM) and night time (10 PM to 6 AM) by Noise Level Meter |
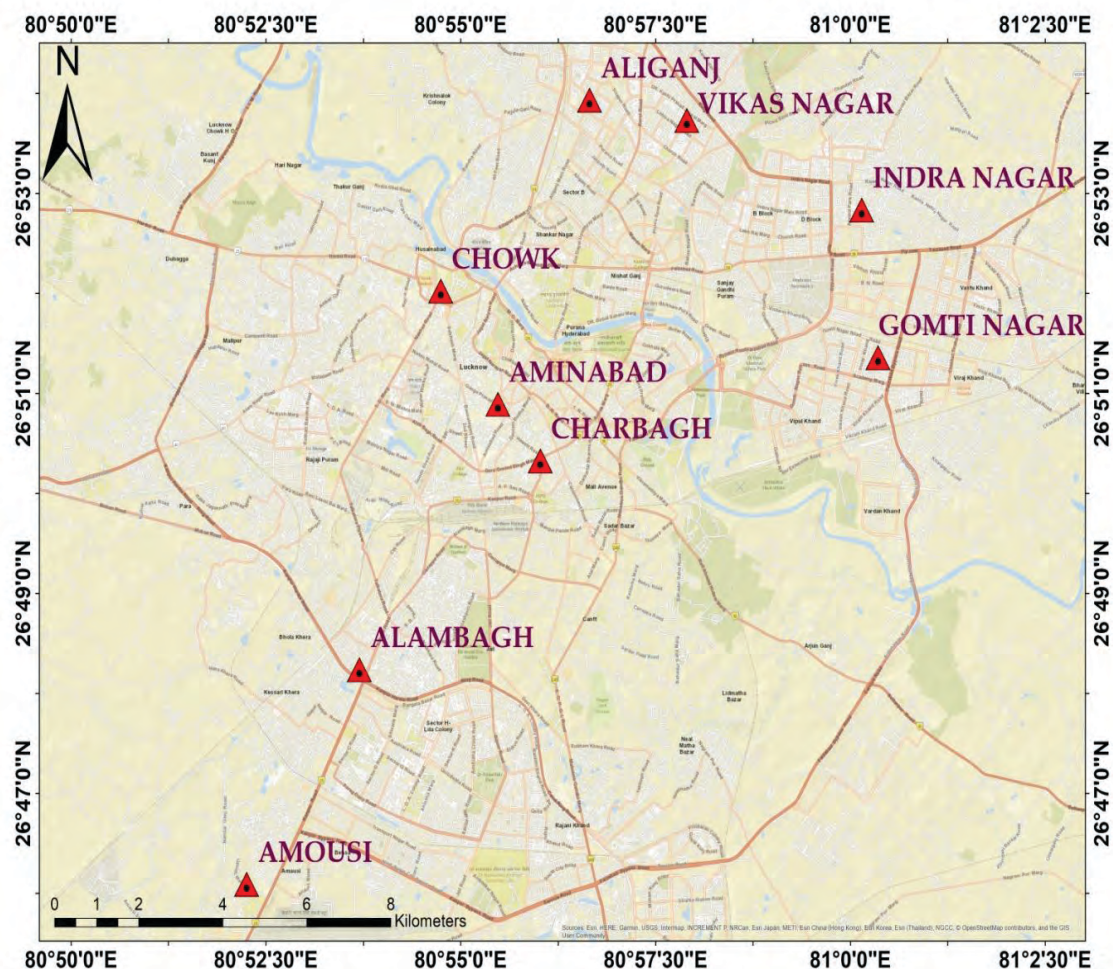
**Figure 2: Ambient Air Pollution Monitoring at 9 Locations in Lucknow City**

## 1.4 RESULTS

The detailed results of air quality monitoring during the Pre-Monsoon period are presented in Table 9 and Figure 3-4.
.

### 1.4.1 Respirable Suspended Particulate Matter (RSPM or PM$_{10}$)

In residential areas (Aliganj, Vikas Nagar, Indira Nagar and Gomti Nagar), the 24 hours concentrations of PM$_{10}$ were in the range of 78.2 to 182.2 µg/m$^3$ with an average of 131.2 µg/m$^3$. The average concentration of PM$_{10}$ was observed highest at Indiranagar among the residential areas.

In commercial areas (Charbagh, Alambagh, Aminabad and Chowk) the concentrations of PM$_{10}$ were in the range of 106.0 to 268.5 µg/m$^3$ with an average of 176.8 µg/m$^3$ respectively. The average concentration of PM$_{10}$ was observed highest at Charbagh among the commercial areas.

In industrial area (Amausi), the average concentration of PM$_{10}$ was 189.6 µg/m$^3$. However, in all locations PM$_{10}$ levels were exceeded the prescribed National Ambient Air Quality Standard (NAAQS) of 100 µg/m$^3$.

### 1.4.2 Fine Particulate Matter (PM$_{2.5}$)

In residential areas (Aliganj, Vikas Nagar, Indira Nagar and Gomti Nagar), the 24 hours concentrations of PM$_{2.5}$ were in the range of 43.4 to 111.3 µg/m$^3$ with an average of 72.2 µg/m$^3$. The average concentration of PM$_{2.5}$ was observed highest at Indiranagar among the residential areas.

In commercial areas (Charbagh, Alambagh, Aminabad and Chowk) the concentration of PM$_{2,5}$ was in the range of 79.3 to 161.1 µg/m$^3$ with an average of 110.4 µg/m$^3$ respectively. The average concentration of PM$_{2.5}$ was observed highest at Charbagh among the commercial areas.

In industrial area (Amausi), the average concentration of $PM_{2.5}$ was 104.7 $\mu g/m^3$. However, in all locations $PM_{2.5}$ levels were exceeded the prescribed National Ambient Air Quality Standard (NAAQS) of 60 $\mu g/m^3$.

### 1.4.3   Sulphur dioxide ($SO_2$)

In residential area (Aliganj, Vikas Nagar, Indira Nagar and Gomti Nagar), the levels of $SO_2$ was in the range of 8.6 to 15.1 $\mu g/m^3$ with an average of 11.1 $\mu g/m^3$. In commercial areas (Charbagh, Alambagh, Aminabad and Chowk) the concentrations of $SO_2$ were in the range of 10.4 to 23.1 $\mu g/m^3$ with an average of 15.0 $\mu g/m^3$. In industrial area (Amausi), the mean level of $SO_2$ was 22.2 $\mu g/m^3$.

However, all the values of $SO_2$ were well below the prescribed NAAQS of 80 $\mu g/m^3$ for all the locations.

### 1.4.4   Nitrogen dioxide ($NO_2$)

In residential areas (Aliganj, Vikas Nagar, Indira Nagar and Gomti Nagar) the 24 hours concentration of $NO_2$ was in the range of 23.1 to 48.4 $\mu g/m^3$ with an average of 34.9 $\mu g/m^3$. In commercial areas (Charbagh, Alambagh, Aminabad and Chowk) the concentration of $NO_2$ was in the range of 25.3 to 54.8 $\mu g/m^3$ with an average of 35.5 $\mu g/m^3$. In industrial areas (Amausi), the average concentration was 39.8 $\mu g/m^3$.

However, all the values of $NO_2$ were within the prescribed NAAQS of 80 $\mu g/m^3$ for all the monitoring locations.

**Table 9: Concentration (µg/m³) of $PM_{10}$, $PM_{2.5}$, $SO_2$ and $NO_2$ during Pre-Monsoon 2022**

| Location | $PM_{10}$ (RSPM) | | | $PM_{2.5}$ | | | $SO_2$ | | | $NO_2$ | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Min | Max | Avg | Min | Max | Avg | Min | Max | Avg | Min | Max | Avg |
| **Residential** | | | | | | | | | | | | |
| Aliganj | 83.9 | 177.9 | 132.6±34.4 | 59.1 | 109.0 | 73.7±16.6 | 10.5 | 14.2 | 11.5±1.3 | 29.9 | 45.1 | 37.4±5.7 |
| Vikas Nagar | 78.2 | 155.4 | 118.2±31.7 | 43.4 | 87.0 | 65.0±19.9 | 8.6 | 12.4 | 9.6±1.2 | 23.1 | 38.3 | 28.4±4.7 |
| Indira Nagar | 93.5 | 182.2 | 142.2±45.0 | 61.6 | 111.3 | 80.5±26.9 | 11.4 | 15.1 | 12.7±2.1 | 33.2 | 48.4 | 40.5±7.6 |
| Gomti Nagar | 80.9 | 166.3 | 131.6±29.4 | 43.5 | 99.0 | 69.5±17.4 | 9.4 | 13.9 | 10.5±1.4 | 25.0 | 43.6 | 33.3±7.5 |
| **Commercial** | | | | | | | | | | | | |
| Charbagh | 158.0 | 268.5 | 203.9±42.4 | 110.2 | 161.1 | 130.1±17.8 | 16.5 | 23.1 | 18.4±2.2 | 36.9 | 54.8 | 41.6±6.3 |
| Alambagh | 126.2 | 207.7 | 176.6±28.6 | 86.3 | 108.0 | 96.1±9.5 | 11.9 | 16.2 | 14.1±1.8 | 26.8 | 43.8 | 31.4±5.7 |
| Aminabad | 106.0 | 179.9 | 149.4±24.3 | 79.3 | 96.9 | 89.4±6.3 | 10.4 | 15.9 | 11.9±2.0 | 25.3 | 38.0 | 31.7±4.5 |
| Chowk | 146.3 | 226.4 | 177.4±25.1 | 102.4 | 136.6 | 125.8±11.6 | 12.5 | 20.5 | 15.6±2.8 | 32.6 | 43.2 | 37.3±4.2 |
| **Industrial** | | | | | | | | | | | | |
| Amausi | 117.1 | 208.4 | 189.6±35.8 | 72.4 | 134.0 | 104.7±23.1 | 18.2 | 28.3 | 22.2±4.0 | 26.0 | 52.6 | 39.8±10.5 |
| NAAQS | | 100 | | | 60 | | | 80 | | | 80 | |
| WHO Guidelines | | 50 | | | 25 | | | 20 | | | 40* | |

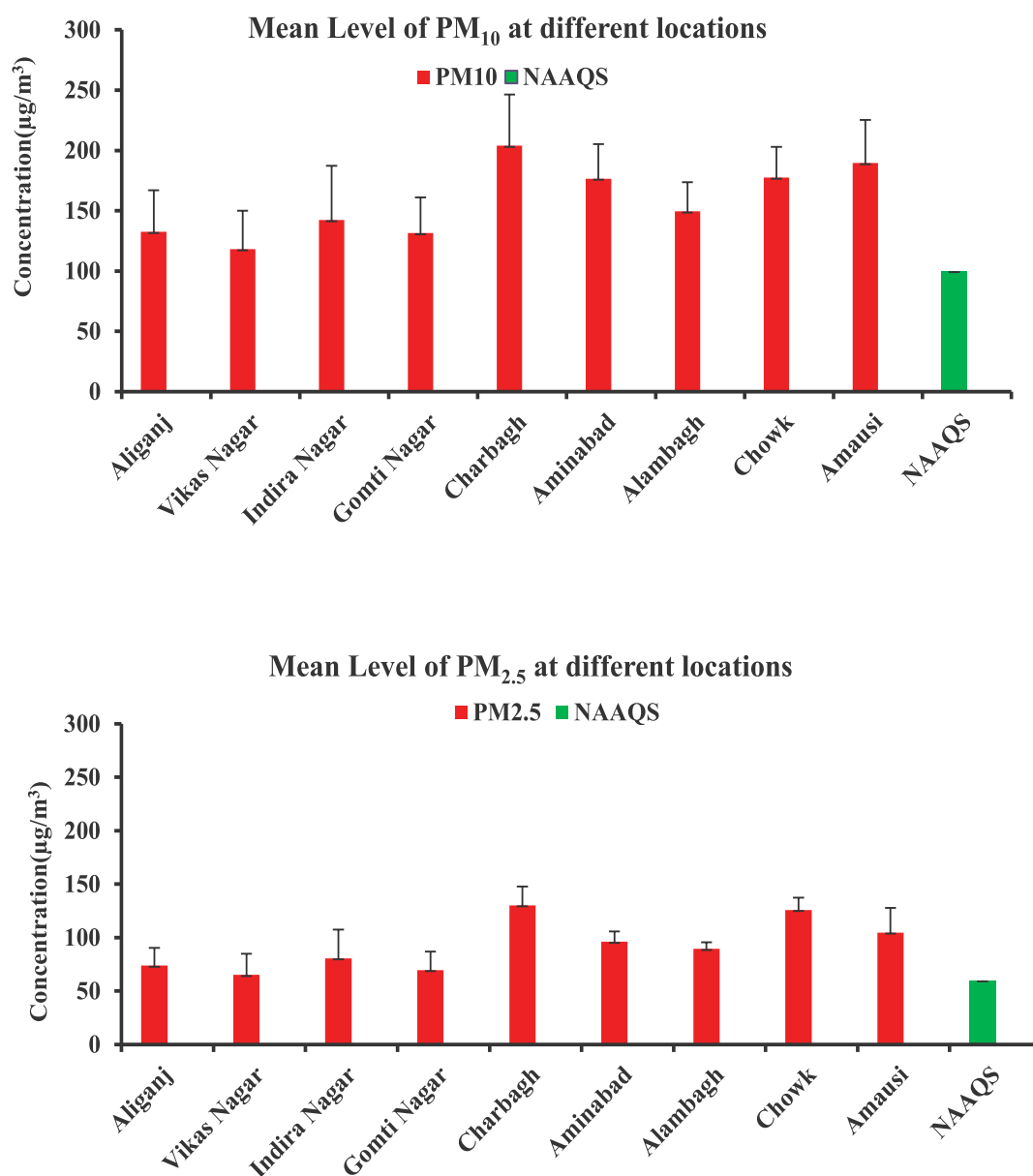*=Annual Average, NAAQS=National Ambient Air Quality Standard

**Figure 3:** Concentration ($\mu g/m^3$) of $PM_{10}$ and $PM_{2.5}$ in different areas of Lucknow city during Pre-Monsoon Season (2022) compared with prescribed National Ambient Air Quality Standard (NAAQS)
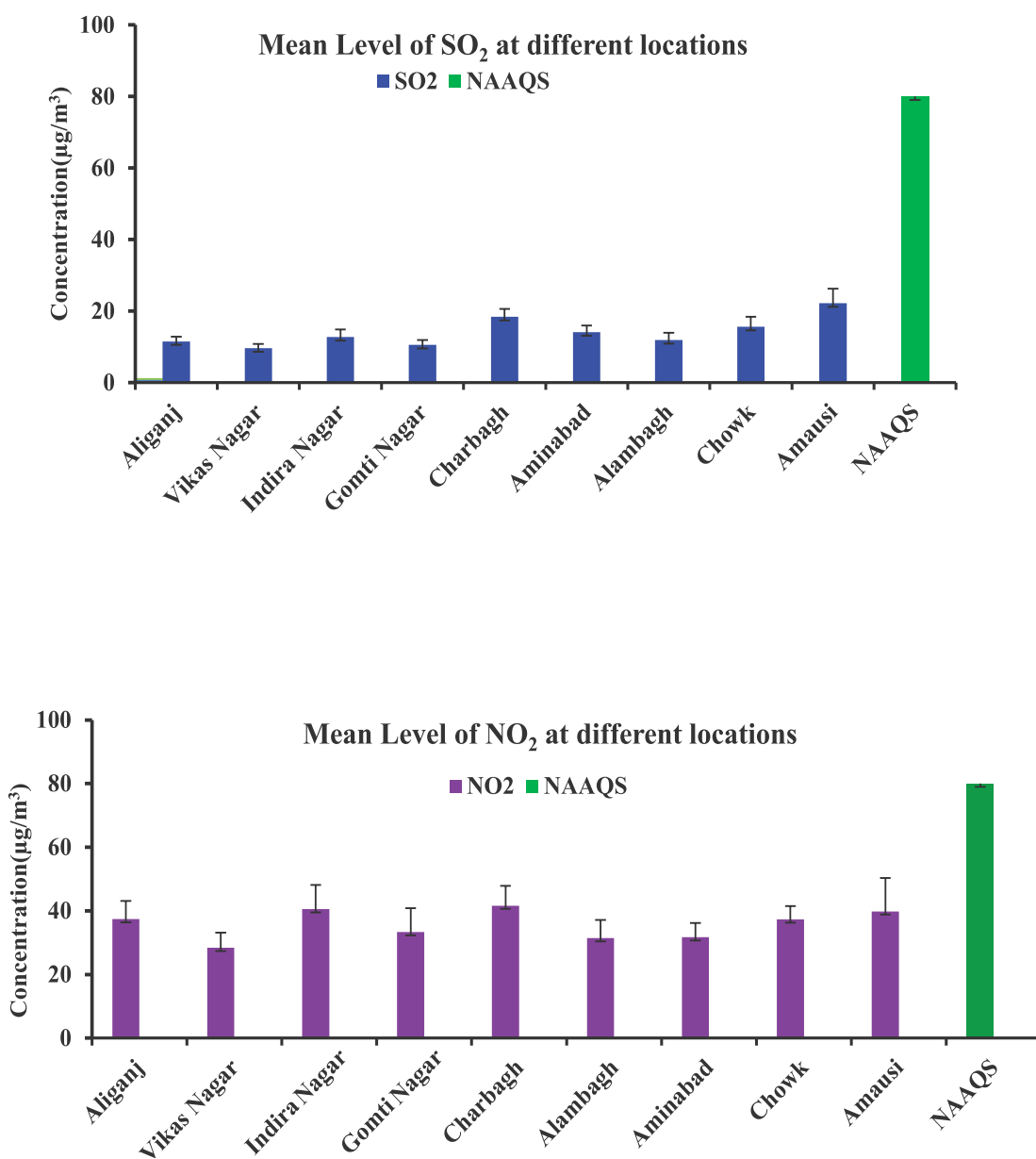
**Figure 4:** Concentration ($\mu g/m^3$) of $SO_2$ and $NO_2$ in different areas of Lucknow city during Pre-Monsoon season (2022) compared with prescribed National Ambient Air Quality Standard (NAAQS)

### 1.4.5 Trace Metals

The concentration of Pb in residential areas ranged between 5.45 (Aliganj) to 15.16 (Vikas Nagar) $ng/m^3$ with an average of 8.70 $ng/m^3$. However, in commercial areas, the values ranged between 9.92 (Alambagh) to 14.60 (Charbagh) $ng/m^3$ with an average of 12.70 $ng/m^3$. In industrial area Amausi, the value of Pb was 9.81 $ng/m^3$.

Besides, the concentration of Ni in residential areas ranged between 1.87 (Gomtinagar) to 3.54 (Indiranagar) $ng/m^3$ with an average of 2.35 $ng/m^3$. However, in commercial areas, the values ranged between 0.86 (Charbagh) to 3.50 (Aminabad) $ng/m^3$ with an average of 2.0 $ng/m^3$. In industrial area Amausi, the values of Ni was 2.53 $ng/m^3$.

### 1.4.6 Noise Level

The noise monitoring data recorded during the Pre-Monsoon period (May, 2022) is presented in Table 10. In residential areas, the day and night time noise levels were recorded with the range from 63.8 to 73.2 and 60.8 to 67.8 dB(A) respectively. All the values were significantly higher than the prescribed national limits of 55 and 45 dB (A) for day and night time respectively.

In commercial and traffic area, the day and night time noise levels were recorded with the range from 79.7 to 86.6 and 67.5 to 75.9 dB(A) respectively. Noise level at all the commercial sites during day and night time were significantly higher than the prescribed national limits of 65 dB (A) and 55 dB (A) for day and night time respectively.

In industrial area Amausi, the day and night time noise levels were recorded 81.3 and 72.9 dB(A) respectively. Noise levels at industrial area were recorded higher than the NAAQS of 75.0 and 70.0 dB(A) respectively.

**Table 10: Noise Level dB(A) during Day and Night Time**

| S. No. | Area | Location | Noise level dB(A) 2022 | | Noise level dB(A) 2021 | |
|---|---|---|---|---|---|---|
| | | | **Day** | **Night** | **Day** | **Night** |
| 1 | **Residential** | Aliganj | 66.1 | 60.8 | 67.6 | 58.1 |
| | | Vikas Nagar | 63.8 | 63.6 | 70.5 | 60.0 |
| | | Indira Nagar | 73.2 | 62.5 | 67.0 | 55.4 |
| | | Gomti Nagar | 72.5 | 67.8 | 70.7 | 56.9 |
| | | **Standard** | **55** | **45** | **55** | **45** |
| 2 | **Commercial** | Charbagh | 82.8 | 75.9 | 72.2 | 61.3 |
| | | Alambagh | 86.6 | 67.5 | 67.2 | 52.3 |
| | | Aminabad | 80.0 | 67.9 | 71.6 | 53.1 |
| | | Chowk | 79.7 | 74.6 | 79.0 | 57.4 |
| | | **Standard** | **65** | **55** | **65** | **55** |
| 3 | **Industrial** | Amausi | 81.3 | 72.9 | 73.6 | 60.1 |
| | | **Standard** | **75** | **70** | **75** | **70** |

## 1.5 TRENDS OF AMBIENT AIR QUALITY IN LUCKNOW CITY

The observed $PM_{10}$, $PM_{2.5}$, $SO_2$ and $NO_2$ for 5 years Pre-Monsoon data have been compared to find out the prevailing trend of air pollution in Lucknow city (Figures 5-8). Slight changes in the values are attributed due to some local environmental, urban development and climatic factors.

### 1.5.1 Trend of $PM_{10}$ and $PM_{2.5}$

Figure 5 and Figure 6 indicate that the $PM_{10}$ and $PM_{2.5}$ concentration is in decreasing trend till 2020 and started increasing from 2021 to 2022. The levels of $PM_{10}$ and $PM_{2.5}$ at all the residential, commercial and industrial areas were relatively higher as compared to monitoring data of previous year 2021 and also exceeded the NAAQS.

In 2022, as all the activities are resumed from the restrictions of COVID-19 pandemic and also significantly increased traffic flow, fugitive combustion and road dust in the city which deteriorated the air quality for Pre- Monsoon 2022.

### 1.5.2 Trend of $SO_2$ and $NO_2$

The level of $SO_2$ and $NO_2$ during Pre-Monsoon since 2018 is presented in Figure 7 and Figure 8 for all the locations. Concentration is in decreasing trend till 2020 and started increasing from 2021 to 2022.  In residential, commercial and industrial areas, higher concentrations of $SO_2$ and $NO_2$ were found compared to that of the previous year 2021. However, all the values of the present study were found to be lower than the NAAQS.
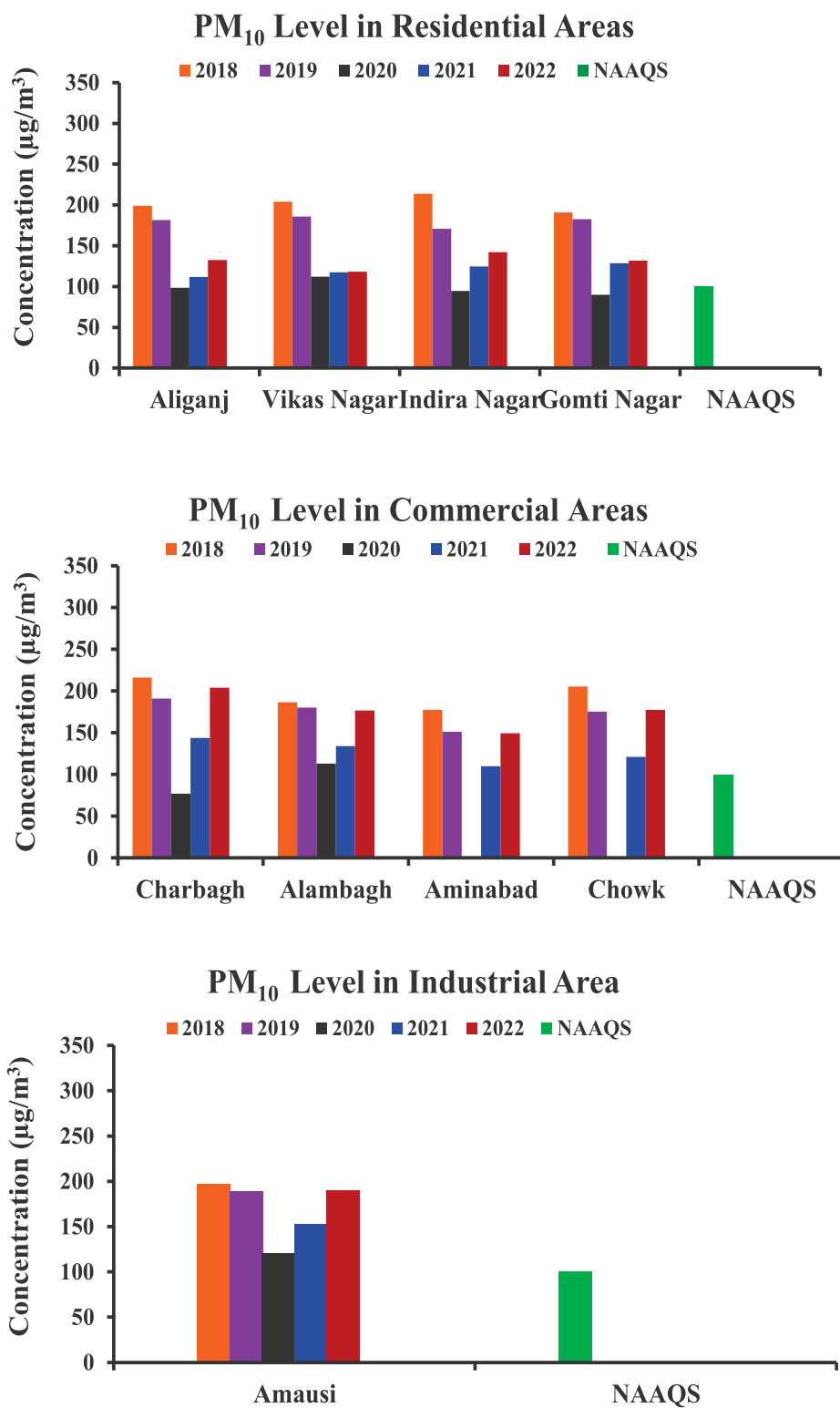
**PM$_{10}$ Level in Residential Areas**



**PM$_{10}$ Level in Commercial Areas**



**PM$_{10}$ Level in Industrial Area**

**Figure 5:** Concentration (μg/m$^3$) of PM$_{10}$ **(**RSPM**)** in Residential, Commercial and Industrial areas of Lucknow city during 2018 to 2022 (Pre-Monsoon) and compared with prescribed National Ambient Air Quality Standard (NAAQS)
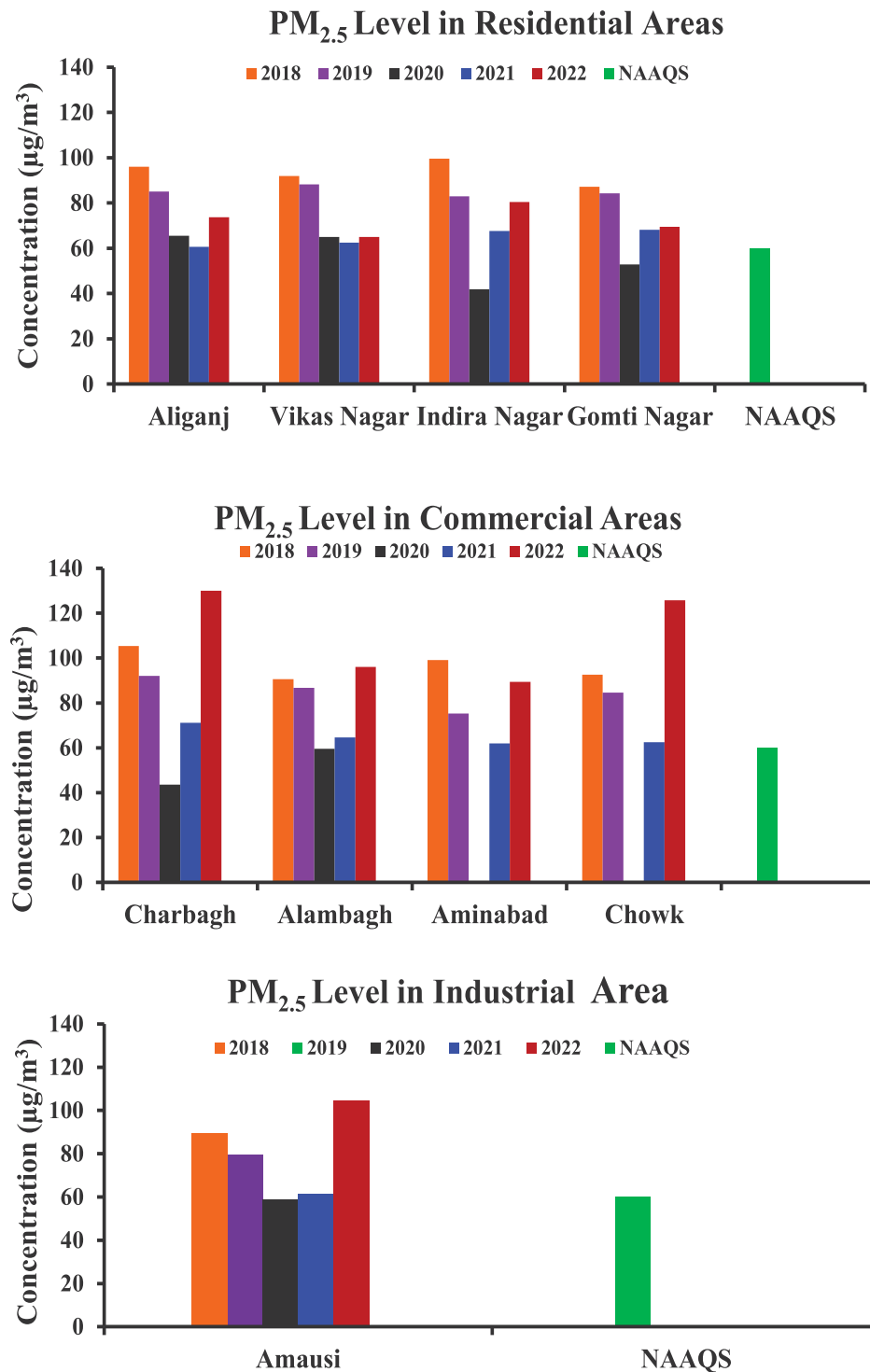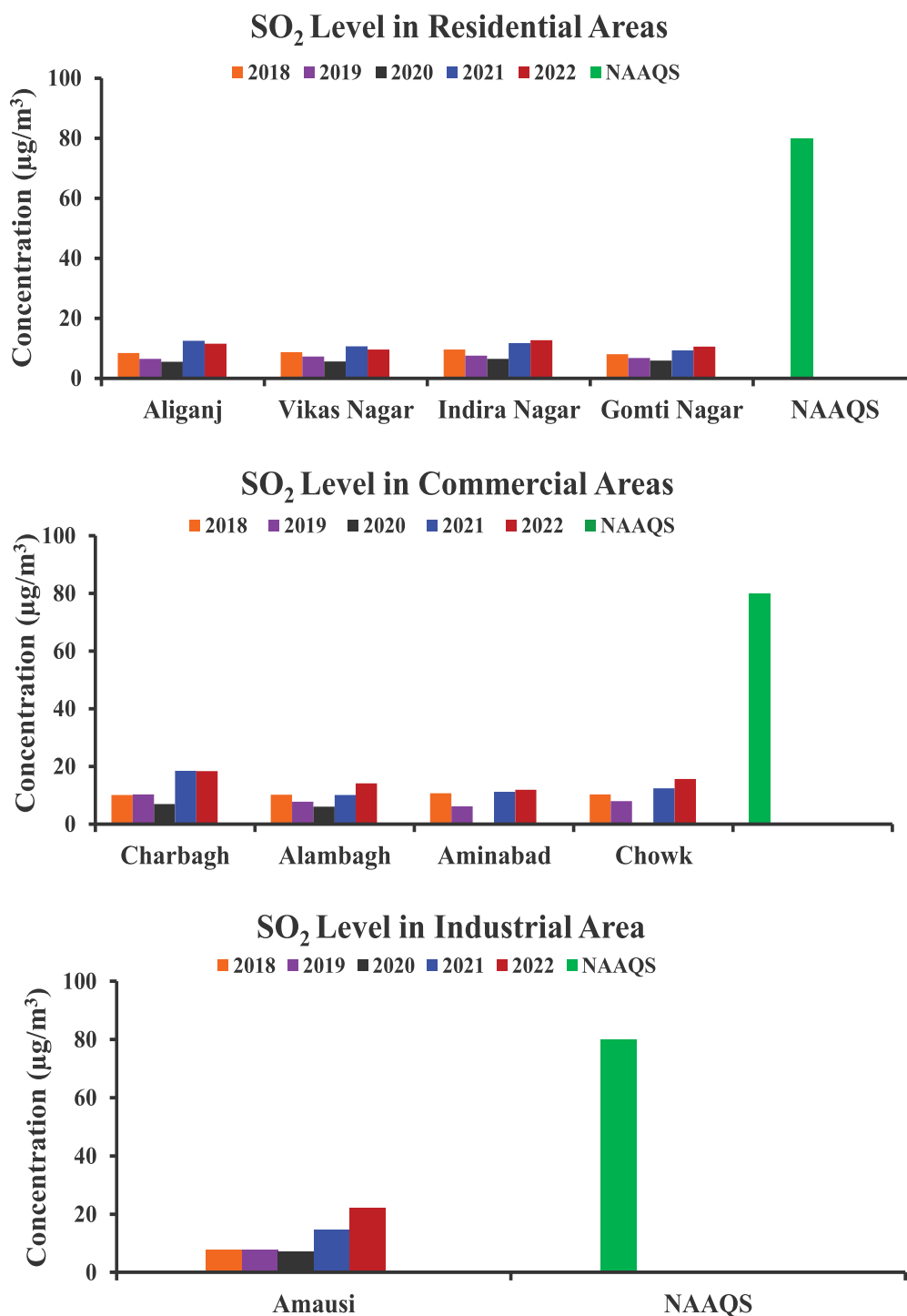
## PM$_{2.5}$ Level in Residential Areas



## PM$_{2.5}$ Level in Commercial Areas



## PM$_{2.5}$ Level in Industrial Area



**Figure 6:** Concentration (μg/m$^3$) of PM$_{2.5}$ in Residential, Commercial and Industrial areas of Lucknow city during 2018 to 2022 (Pre-Monsoon) and compared with prescribed National Ambient Air Quality Standard (NAAQS)
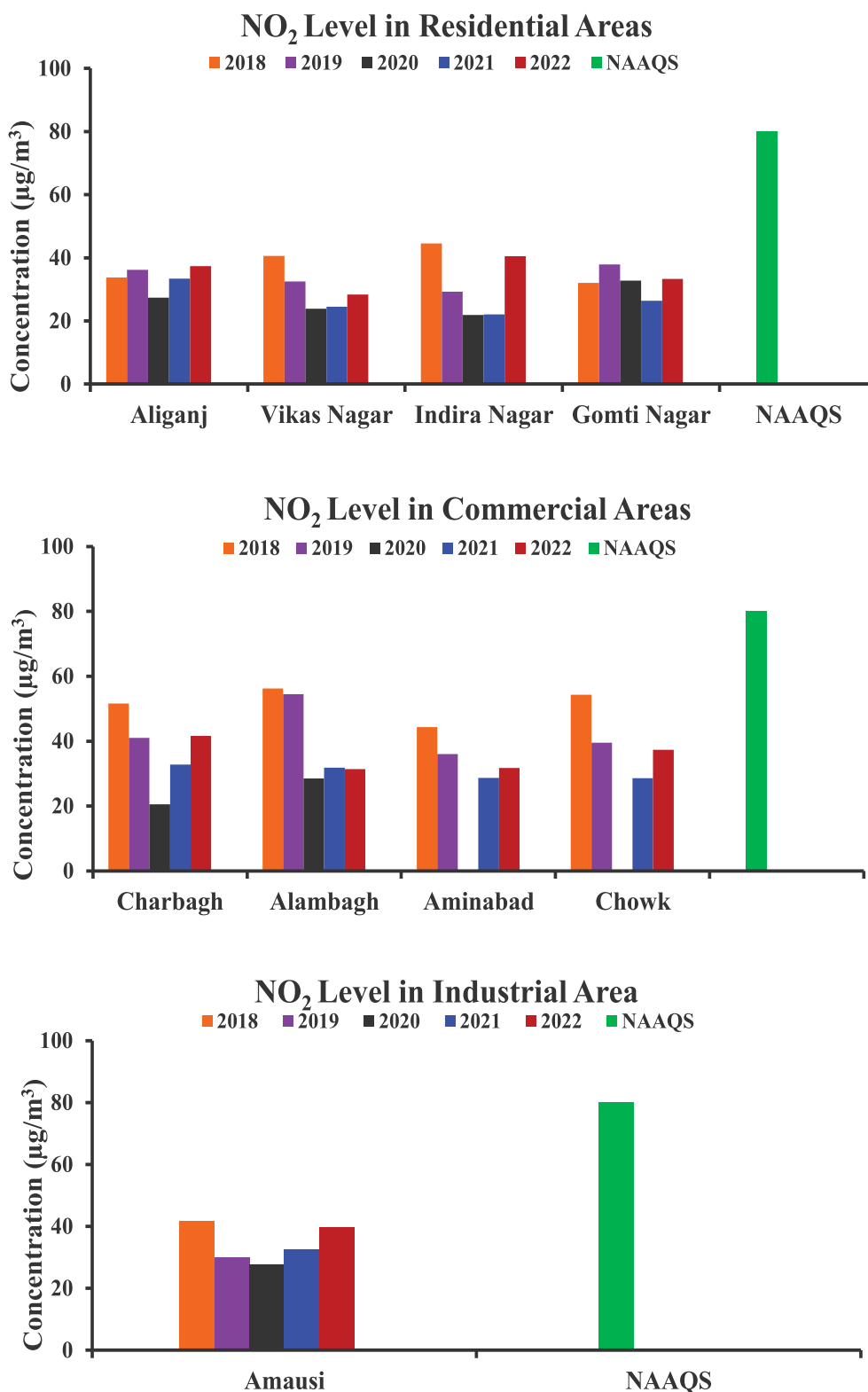
**Figure 7:** Concentration ($\mu g/m^3$) of $SO_2$ in Residential, Commercial and Industrial areas of Lucknow city during 2018 to 2022 (Pre-Monsoon) and compared with prescribed National Ambient Air Quality Standard (NAAQS)

## NO$_2$ Level in Residential Areas



## NO$_2$ Level in Commercial Areas



## NO$_2$ Level in Industrial Area



**Figure 8:** Concentration (μg/m³) of NO$_2$ in Residential, Commercial and Industrial areas of Lucknow city during 2018 to 2022 (Pre-Monsoon) and compared with prescribed National Ambient Air Quality Standard (NAAQS)

### 1.5.3    Noise Level

Current year's Pre-Monsoon noise data was compared with the corresponding data of the previous four years i.e. 2018 to 2022 and results are presented in Figure 9 and 10. Noise pollution is the spread of unwanted sounds into the environment. Unwanted sounds have a range of mental health effects. The brain is always monitoring sounds for signs of danger, even during sleep. With continued exposure to noise pollution can trigger anxiety or stress. The higher noise levels adversely affect the lives of millions of urban people. Studies have shown that there are direct links between noise and health. Problems related to noise include stress related illnesses, high blood pressure, speech interference, hearing loss, sleep disruption, and lost productivity. People living with noise pollution may feel irritable, on edge, frustrated, or angry.  If a person feels they cannot control the amount of noise in their environment, its impact on their mental health intensifies.

### 1.5.3.1 Day time Noise Level

All residential, commercial cum traffic and industrial areas showed slightly increasing trend over that of the previous year. The comparative data are presented in Figure 9.

### 1.5.3.2 Night time Noise Level

All residential, commercial cum traffic and industrial areas showed slightly increasing trend over that of the previous year. The comparative data are presented in Figure 10.
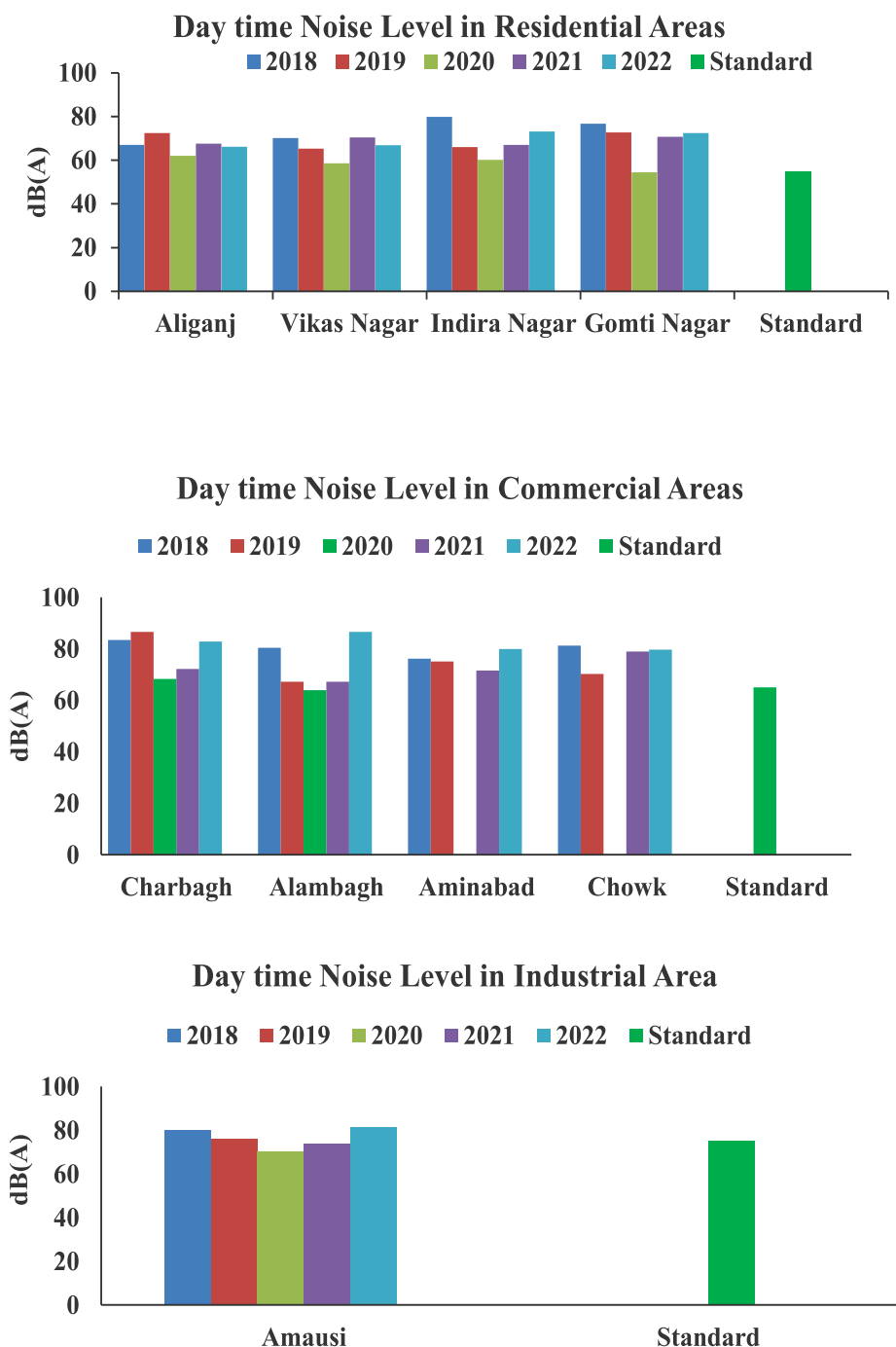
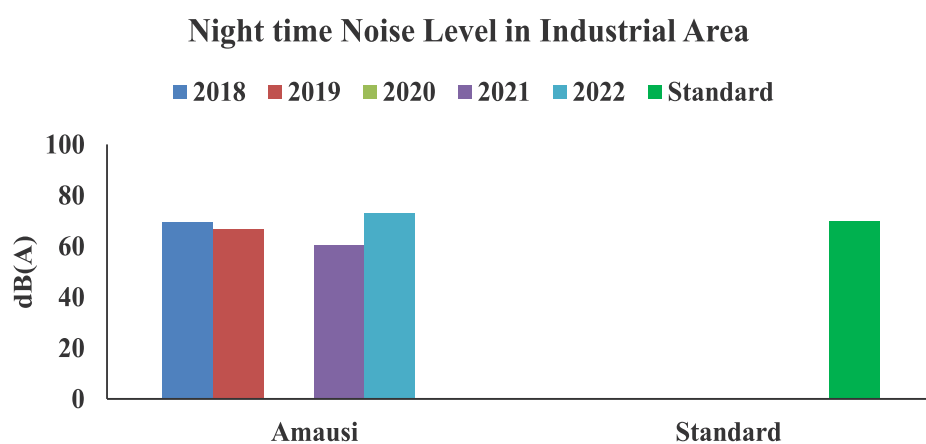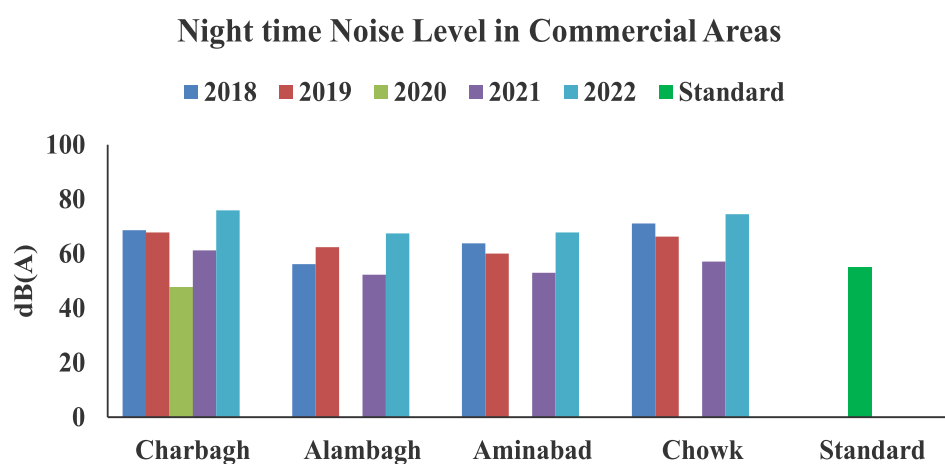**Figure 9:** Comparison of day time Noise Level in dB(A) for different areas of Lucknow city (Pre-Monsoon 2018-2022)
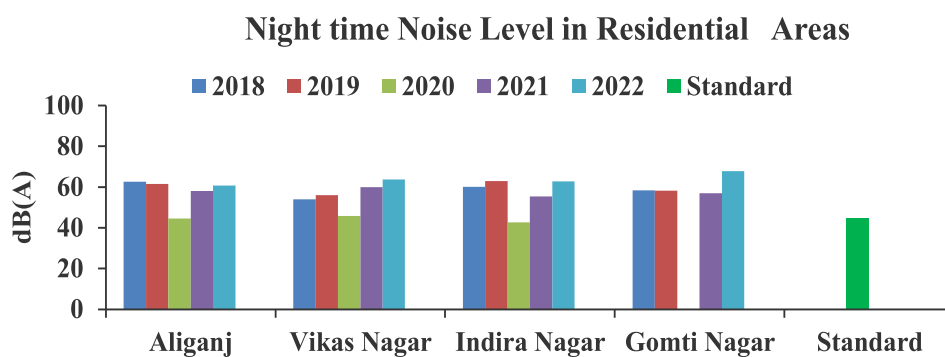
## Night time Noise Level in Residential   Areas

■ 2018  ■ 2019  ■ 2020  ■ 2021  ■ 2022  ■ Standard



## Night time Noise Level in Commercial Areas

■ 2018  ■ 2019  ■ 2020  ■ 2021  ■ 2022  ■ Standard



## Night time Noise Level in Industrial Area

■ 2018  ■ 2019  ■ 2020  ■ 2021  ■ 2022  ■ Standard



**Figure 10:** Comparison of night time Noise Level in dB(A) for different areas of Lucknow city (Pre-Monsoon 2018-2022)

## 1.6 CONCLUSIONS / MAIN FINDINGS

CSIR-IITR has monitored air pollutants such as $PM_{10}$, $PM_{2.5}$, $SO_2$, $NO_2$ and toxic heavy metals Lead (Pb) and Nickel (Ni) at 9 locations for the assessment of ambient air quality during the month of April-May 2022. Besides, day and night time noise levels were also monitored at the same locations. The main findings of the study are as follows:

### Vehicles

➢ As on 31st March 2022, the RTO registered vehicles all types in Lucknow city is 2650286 (2021-22) i.e. increased by 5.4% (increase 135825 vehicles) with compared to last year registered vehicle 2514461 (2020-21).

➢ The CNG vehicles of all types increased from 36017 (2020-21) to 42567 (2021-22) by 18.18% (6550 vehicles).

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### Fuel Consumption

➢ Petrol and CNG consumption increased during 2021-22 but the diesel consumption decreased.

➢ The petrol consumption for the year 2021-22 was 207417.5 kL i.e. increase by 8.51% (in kL 16268.5) with compared to last year petrol consumption 191149.0 kL (2020-21).

➢ The diesel consumption decreased by -11% (decrease in kL 19440). The diesel consumption was 157220 kL (2021-22) with compared to last year 176660 kL (2020-21).

➢ The CNG consumption for the year 2021-22 was 69295471 kg i.e. 158 % (increase in kg 42434821) with compared to last year CNG consumption 26860650 kg (2020-21).

## Particulates and Gases

➢ The Pre-Monsoon, 2022 $PM_{10}$ concentration has increased by 24.2% with compared to last year Pre-Monsoon 2021 $PM_{10}$ data while the $PM_{2.5}$ concentration has increased by 43.9% with compared to last year Pre-Monsoon 2021 $PM_{2.5}$ data.

➢ The average level of $PM_{10}$ (157.9 $\mu g/m^3$) and $PM_{2.5}$ (92.8 $\mu g/m^3$) at all the monitoring locations of residential, commercial and industrial areas were higher than their respective NAAQS of 100 $\mu g/m^3$ for $PM_{10}$ and 60 $\mu g/m^3$ for $PM_{2.5}$. The average concentration of $PM_{10}$ has exceeded by 57.9% with respect to its standard value (100 $\mu g/m^3$) while average concentration of $PM_{2.5}$ by 54.6 % with respect to its standard value (60 $\mu g/m^3$).

➢ The concentration of gaseous pollutants, $SO_2$ and $NO_2$ were below the prescribed NAAQS (80 $\mu g/m^3$) at all the locations but Pre-Monsoon 2022 gaseous pollutant concentrations were higher at all locations w.r.t. Pre-Monsoon 2021. The average values of $SO_2$ and $NO_2$ have increased by 5.02 % and 12.2 % respectively.

## Noise

➢ The day and night time noise levels at residential and commercial areas have exceeded about 26.6 % & 26.5% during day times and 41.5% & 30% during night times respectively in comparison with the prescribed standards (55 dB(A) for day and 45 dB(A) for night times). However, noise levels of Pre-Monsoon 2022 were relatively high at all the locations w.r.t. noise levels of Pre-Monsoon 2021.

Since, Lucknow is a rapidly growing city, air pollution may not be zero but efforts should be taken to decelerate the rising trend of pollution. It would be an achievement even air pollution increasing rate is slowed down with progress of time. To resolve the serious air pollution issue, comprehensive studies and continuous actions are required for better management of air pollution in Lucknow city. Public participation also is equally important for proper implementation of rules, time to time formulated by Regulatory Agencies.

## 1.7    HEALTH IMPACT OF AMBIENT PARTICULATE MATTER

**Relationship between ambient $PM_{2.5}$ Concentration v/s morbidity and mortality of population**

Recently, with accelerated urban development and modernization, air pollution is worsening and its impact on human health has become an important research topic. Currently, many researchers paid more attention to the association between air pollution and respiratory system disease. $PM_{2.5}$ (particles less than 2.5 micrometers in diameter) can penetrate deeply into the lung, irritate and corrode the alveolar wall, and consequently impair lung function.

**Pathogenicity of Particulate Matter**

Air pollutants include gaseous pollutants and particle matters (PM). The pathogenicity of PM is determined by their size, composition, origin, solubility and their ability to produce reactive oxygen. Studies have shown that smog is generally caused by a high concentration of fine particles. Moreover, adults exposed to other high levels of ambient air pollution, for example $PM_{10}$ and coarse particulate, also have shown increased prevalence of respiratory disease. Studies in toxicology, epidemiology and other related fields have demonstrated that respirable particles are closely related to the incidence of human diseases and mortality rate.

**Relationship between non-accidental death and $PM_{2.5}$**

Patients with respiratory diseases account for a large proportion of these non-accidental deaths caused by air pollution. Given that $PM_{2.5}$ causes asthma, and respiratory inflammation; jeopardizes lung functions and even promotes cancers, its impact on human respiratory system should not be dismissed. The ❒Harvard six Cities Study❒, published in 1996, revealed that $PM_{2.5}$ was one of the causative factors of human non-accidental death. After many years of epidemiological studies, scientists have revealed a significant correlation between fine particle pollutants and respiratory morbidity and mortality. A report from the last century illustrated that increased PM concentration in the air may directly lead to an elevated morbidity and mortality of a population. $PM_{2.5}$ can decrease the average life span from few months to years.

## 1.8    RECOMMENDATIONS FOR MITIGATION OF AIR POLLUTION

1. Pick-up and drop points should be identified away from the traffic intersections.

2. Open trucks carrying garbage/solid wastes /sands/cement/concretes/loose materials must properly be covered. Overloaded trucks which usually spill garbage along the road must be checked.

3. Carpet Grass and more plantations are encouraged all along the major roads.

4. Regular vacuum-assisted sweeping and watering of roads using sprinklers can prevent the resuspension of soil and silt load.

5. There should be better house-keeping, minimizing burning of biomass, switching to cleaner fuels, and ensuring not to through the generated wastes/ash to road sides or drains by food stalls, restaurants, and open cooking and tandoors etc. Proper collection and disposal of wastes is required.

6. Implementation of BS-VI and encouraging electric/biodiesel/CNG/ hybrid vehicles for public transport.

7. Synchronization of adjacent traffic signals will help the traffic flow smoothly and introduce in the lane driving

8. Haphazard road side vehicle parking must be avoided to manage traffic jam.

9.  Proper collection of Municipal Solid Waste and disposal in time bound manner. Burning of MSW should be completely banned.

10. Electrical or gas-based crematorium practices shall be encouraged.

11. To prefer public transport over personal transport

12. Vehicle Scrub centres are required  for old and phased-out vehicles

13. Continuous electric power supply to reduce Diesel Generator operation time

14. Social awareness programs for sensitizing public about the clean air practices.

15. Shifting of major godowns to outside areas to prevent the movement of heavy vehicles inside the city.

We express our sincere thanks and gratitude to the following persons as they have provided required data with respect to vehicular population, transport, fuel consumption (Petrol/Diesel/CNG/LPG/Green Gas) for this report:

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**Mr. Prashant Dixit, Assistant Regional Manager**, City Transport Services Ltd. Gomtinagar, Lucknow,

**Mr. Manoj Sharma, Assistant Regional Manager**, **Dr. Sunil Upadhyay Senior Station Incharge,** City Transport Services Ltd, Dubagga Depot, Lucknow,

**Mr. Gaurav Kumar, Sr. Manager**, Retail Sales, IOC, Lucknow,

**Mr. Vineet Chopra, Chief Manager**, Business Planning (Retails), U.P., BPCL **Mr. Shantanu Singh, Sales Office**r, BPCL, Lucknow

**Mr. Arvind Singh, Dy. Gen. Manager**, HPCL, Lucknow,**Ms Shiva Nigam** (RE & Analytic), HPCL, Lucknow

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# सीएसआईआर-भारतीय विषविज्ञान अनुसंधान संस्थान
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