# ASSESSMENT OF AMBIENT AIR QUALITY OF LUCKNOW CITY

## PRE-MONSOON 2017

## FINDINGS OF A RANDOM SURVEY

Photo : Hazratganj, Lucknow, June 2, 2017

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# ASSESSMENT OF AMBIENT AIR QUALITY OF LUCKNOW CITY DURING PRE-MONSOON, 2017


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# Salient Features of the Study

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|---|---|
| ❖ **Geographical Position** | : 26° 52' N Latitude<br>80° 56' E Longitude<br>128 m above Sea Level |
| ❖ **Area** | : 310 sq. km. |
| ❖ **Population** | : 28,15033 as per 2011 Census |
| ❖ **Projected Population** | : 65 lakhs as per Master Plan 2031 |
| ❖ **General Climate of Lucknow city** | : 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 Population in Lucknow city as on 31/03/2017** | : 19,78,345 |
| ❖ **Growth of Vehicle over 2015-2016** | : 6.1% |
| ❖ **Total No. of Filling Stations (Petrol/Diesel/CNG)** | : 123 |
| ❖ **Consumption of Petrol** | : 1,93,345 KL |
| ❖ **Consumption of Diesel** | : 2,30,626 KL |
| ❖ **Consumption of CNG** | : 3,21,34,736 Kg |
| ❖ **Major Sources of Pollution** | : Automobiles, D. G. sets, Construction activities |
| ❖ **Parameters Monitored** | : $PM_{10}$, $PM_{2.5}$, Sub-fraction of fine Particles, $SO_2$, $NO_X$, trace metals and noise levels |
| ❖ **Study Conducted by** | : Environmental Monitoring Division CSIR- IITR, Lucknow |

**ASSESSMENT OF AMBIENT AIR QUALITY OF LUCKNOW CITY DURING PRE-MONSOON, 2017**

## 1.0 SUMMARY

*The study was carried out during the months of April-May, 2017 to assess the status of air quality by monitoring and assessment of some selected air pollutants namely Respirable Suspended Particulate Matter (RSPM or $PM_{10}$), Fine particles ($PM_{2.5}$), Sulphur Dioxide ($SO_2$), Oxides of Nitrogen (NOx) and trace metals-Lead (Pb) and Nickel (Ni)and noise level at 9 representative locations, categorized as residential (four), commercial (four) and industrial (one) areas in Lucknow city. The results revealed the 24 hours concentration of $PM_{10}$ to be in the range of 140.5 to 310.6 µg/m$^3$ with an average of 222.8 µg/m$^3$. The 24 hours concentration of $PM_{2.5}$ was found to be in the range of 66.7 to 169.0 µg/m$^3$ with an average of 109.4 µg/m$^3$. The average values of $PM_{10}$ and $PM_{2.5}$ irrespective of locations were found to be above the permissible limit (100 µg/m$^3$ for $PM_{10}$ and 60 µg/m$^3$ for $PM_{2.5}$ prescribed by MoEF). Twenty four hours concentration of $SO_2$ and NOx were found to be in the range of 6.8 to 16.7 and 25.7 to 97.8 µg/m$^3$ with an average concentration of 11.7 and 49.7 µg/m$^3$ respectively and all the values were below the permissible limits (80 µg/m$^3$). The mean level of trace metals were* Pb = 219.97 and Ni = 48.34 ng/m$^3$. *Noise levels during day and night time were found to be in the range of 65.8 to 81.4 dB (A) and 56.3 to 67.4 dB (A) respectively which was above the respective permissible limits except in industrial area.*

## 1.1 INTRODUCTION

Air pollution and related epidemiological studies reported throughout the world revealed that air pollutants are one of the important mass human killers besides its effect on global warming as well as climate change. Reports suggest that immediate sincere attention is required to bring down the air pollutants level and to move towards successful implementation of our national mission i.e. Swachch and Swasth Bharat. It is known that air pollution is a serious issue as millions of people especially in urban area are exposed to high levels of air pollutants, mainly to particulate pollution and some selected gaseous pollutants, likely oxides of nitrogen and surface ozone.

Urban air pollution is mainly caused by burning of fossil fuels (Diesel, petrol, CNG, LPG by vehicles, diesel by generator sets and LPG by cooking, etc), burning of solid waste especially municipality waste etc, re-suspension of soil, construction activity and nearby burning of agriculture waste etc.

Source of urban air pollutants are multiple and their combined effects make pollutants composition complex and variable. The level of pollutants and fate (speciation) also depends on the source and fuel type, technological development and micrometeorological conditions.

Generally the main sources of air pollutants in our major cities are similar. There are several organizations in India which are engaged in urban pollution studies and have reported that particulate matters ($PM_{10}$ and $PM_{2.5}$) levels are much higher than the permissible limit. Particulate matter is a carrier of other pollutants associated with it, like trace elements (Fe, Ca, Pb, Cu, As, Cd, Al, Na, K, Zn, Cr, Co, Ni etc.) and organic pollutants like Poly aromatic hydrocarbon (PAHs) etc., which are responsible for human health effects.

CSIR-IITR, Lucknow took the issue seriously, way back in 1997 and has been striving hard since then for creation of mass awareness among public, scientific community,

academicians and regulatory authorities. We have ensured skill development of sizable number of students, by providing training, in the areas of monitoring, testing and management of air pollutants. In this connection, CSIR-IITR has been assessing ambient air quality of urban area of Lucknow city during pre (April and May) and post (Sept and October) monsoon with respect to criteria pollutants namely Particulate Matter, $SO_2$ and $NO_x$ since 1997.

Lucknow is a fast growing city. In 1951, area of Lucknow was 48 sq km which has now increased to 310 sq.km in 2011. As per 2011 census, the city has a population of 28.15 lakh (Municipal Corporation + Cantonment).

In the proposed master plan 2031 (Lucknow Development Authority), the area of the city will increase to 654 sq.km by inclusion of 197 villages, with a projected population of 65 lakh. This will lead to the change of land use plan of existing open/ agricultural area to residential, commercial or industrial. The net result would be more activities and more population. The, first phase of metro rail construction from Airport to Charbagh railway station is still to be completed, and the $2^{nd}$ phase (underground) from Charbagh to Parivartan chowk and then onwards to Munshipulia via IT Chauraha is under progress. Traffic on these main routes of the city is badly affected. Particularly the fleet of special purpose vehicle (Luxury low floor CNG city buses) operated by Lucknow City Transport Services Limited (LCTSL) have been forced to change their route due to metro construction resulted in the drastic downfall (about 50%) in passenger numbers. The passengers have begun to use small vehicle (autos etc) on regular routes (narrowed due to metro construction) with more vehicles and heavy traffic jam leading to high emission during the construction phase along the metro rail route.

During the past 20-25 years, a large number of shops, hospitals, hotels etc. were opened in the residential areas of newly developed colonies. Most of the main and side lanes are full of encroachment. The vehicle parking by consumers is one of the major causes of traffic jams across the city. The garbage dumps on roads release

pollutants and disease causing microbes. When the garbage spreads on the road, it is crushed by vehicles and fine dust comes into air, resulting in its conversion to a significant air pollution source. These activities also add to the pollution level of the city.

Vehicular traffic is the main source of particulate air pollution in Lucknow city. The number of different categories of vehicles registered with RTO (Regional Transport Office) Lucknow is 19, 78,345 as on 31.03.2017 which is 6.10% higher over the last year (Table 1). Uttar Pradesh State Road Transport Corporation (UPSRTC) introduced bus services under the banner "*Lucknow City Transport Services Limited*" on different routes of Lucknow city. The details of bus routes and number of buses plying as on 31.03.2017 are given in Table 2. In Lucknow city there are 123 filling stations for petrol, diesel and CNG operated by different oil and gas companies (Table 3).

As per Oil Marketing Company (IOC, BPC and HPCL), the consumption/sale of petrol and diesel was 1,93,345 and 2,30,626 KL as on 31-03-2017. It is observed that petroleum sale has increased by 11.36% whereas sale of diesel has increased by 26.38%. (Table 4). In Lucknow there are nine CNG filling stations and consumption of CNG in the last year was approximately 3,21,34,736 kg (2016-17) which was 6.24% higher than the previous year (2015-16) (Green Gas Limited, Lucknow). Distribution and number of CNG vehicles in Lucknow is summarized in Table 5. The expansion of city is still continued, converting the land use from agricultural to residential/ commercial/ industrial. As a result, there has been an increase in air pollution levels of the city. Considering the above, assessment of ambient air quality of Lucknow city was carried out at 9 locations during pre monsoon (April-May), 2017 with respect to $PM_{10}$, $PM_{2.5}$, sub-fraction of fine particles, $SO_2$, $NO_x$, trace metals and noise level with the following aims and objectives.

- *To assess the ambient air quality with respect to $PM_{10}$, $PM_{2.5}$, $SO_2$, NOx, and trace metals (Ni and Pb) associated with $PM_{10}$.*
- *To study trends of pollutants over a period of time.*
- *To assess day and night time noise levels.*
- *To create a database for future use.*
- *To create public awareness about environmental pollution.*

**Table 1**
**Comparison of Vehicular Population in Lucknow**

| S.No. | Type of Vehicle | Number of Registered Vehicles as on 31st March | | % Change |
|---|---|---|---|---|
| | | 2015-16 | 2016-17 | |
| 1 | Multi Articulated | 3891 | 3556 | -8.61 |
| 2 | Light, Medium and Heavy weight Vehicles (Four wheeler) | 23188 | 26225 | 13.09 |
| 3 | Light commercial vehicles (Three wheeler) | 3537 | 3408 | -3.65 |
| 4 | Buses | 3466 | 3324 | -4.09 |
| 5 | Taxi | 11957 | 10003 | -16.34 |
| 6 | Light Motor Vehicles (Passenger) | 9019 | 7606 | -15.67 |
| 7 | Two wheelers | 1480458 | 1582255 | 6.88 |
| 8 | Car | 267012 | 274853 | 2.94 |
| 9 | Jeep | 30399 | 35592 | 17.08 |
| 10 | Tractor | 25094 | 24919 | -0.70 |
| 11 | Trailors | 1648 | 1727 | 4.79 |
| 12 | Others | 4887 | 4877 | -0.20 |
| **Total** | | **18,64,556** | **19,78,345** | **6.10** |

*Source: RTO, Lucknow*

**Table 2**
**Details of Lucknow City Bus Service, 2017**

| S. No | Route No. | To and Fro | No. of Buses | Frequency |
|---|---|---|---|---|
| 1 | 11 | BBD – Chinhat - Gomti Nagar - Alambagh | 12 | 15 minute interval |
| | | Malhaur Railway Station - Gomti Nagar - Dalibagh - Charbagh | | |
| | | Charbagh - Alambagh - Avadh Hospital - SGPGI | | |
| | | Charbagh - Alambagh - Sardar Patel Dental College | | |
| | | BBD - Chinhat - Awadh Hospital | | |
| | | Charbagh - Alambagh - BBAU | | |
| | | Charbagh - Alambagh - Gopesh Kunj - Kalindi Park | | |
| | | Khargapur - Patrakarpuram - Alambagh | | |
| 2 | 12 | Barabanki - Safedabad Crossing - Ramswarup College - Tewariganj -BBD - Chinhat - HAL Nishatganj - Sikindrabad - KKC College - Charbagh | 24 | 15 minute interval |
| 3 | 12 D | Charbagh – KKC- Vikas Deep-Husainganj-Burlington—Bapu Bhawan- GPO-Shakti Bhawan- Sikanderbagh-Dainik Jagaran-Trikonia Park- FUN Republic-Lohia park-BB D Academy- CMS- Vishal Khand—PS Gomtinagar-Chinhat More-matiaretoraha-mati-DEVA. | 05 | 45 minute interval |
| 4 | 23 | Integral University-Gudamba-Vikasnagar– Nishatganj-Sikandrabad - Hussainganj - Alambagh - Rajnikhand | 17 | 10 minute interval |
| | | Gudamba - Badshanagar - Avadh Hospital | | |
| 5 | 31 | IM Sector Q-Beligaradh-PNT-Purania-Kapoorthala-ChanniLaL -Mahanagar -Gole market - Badhshanagar-Nishatganj - Hussainganj - Charbagh - Alambagh Chouraha. | 2 | 60 minute interval |
| 6 | 31 A | Charbagh - Hussainganj - Sikandrabagh - Gokhale Marg - Nishatganj - Badshahnagar - Gole market - Channilal-Kapoorthala-Purania-Engineering College - Sewa Hospital - Bakshi Ka Talab | 1 | 120 minute interval |
| 7 | 33 | Engineering College - Charbagh - Alambagh - Scooter India | 12 | 20 minute interval |
| 8 | 33 C | Bhitoli - CDRI Chowraha - Jankipuram - Purania - Mahanagar -Badshahnagar - Nishatganj - Hussainganj - Charbagh - Alambagh Cowraha. | 4 | 20 minute interval |
| 9 | 33 S | Bhitoli Chowraha - Engineering College – Kapoorthala - Badshahnagar – Nishatganj – Hussainganj – Charbagh – Alambagh -Bhudeswar Chowraha - Dr. Sukuntala Mishra University. | 1 | 180 minute interval |
| 10 | 33 PGI | SGPGI - Telibagh - Alambagh - Charganj - Hussainganj - GPO -Mahanagar - Engineering College. | 8 | 12 minute interval |
| 11 | 33 LU | Parivartan Chowk - IT Chowraha - Vivekananda | 2 | 45 minute |

| | | | | |
|---|---|---|---|---|
| | | Hospital -Kapoorthala - Engineering College - New Campus Lucknow University | | interval |
| 12 | 43H | New High Court-Polytechnic-Munshiphulia-Khuramnagar Chowraha-Jagrani Chowraha-Teriphulia-Dubagga Chowraha | 04 | 45 minute interval |
| 13 | 45 | Virajkhand - Gomti Nagar - Charbagh - Alambagh - Paasi Kila -Aurangabad - Shahid path | 14 | 15 minute interval |
| 14 | 48.B | Kesarbagh-Bapubhawan-Chief minister house-Lohia Chowraha-Polytechnic-Aahimou-Khurdahi Bazar-Gosainganj-Haidergarh/ | 02 | 120 minute interval |
| 15 | 500 S | Raja Suchana Aayog-Kamta Chowraha-Aahimau-Uttaria-PGI-Mohanlalganj-Sisandhi | 01 | 120 minute interval |
| | | **Total** | 107 | |

*Source: Lucknow City Transport Services Limited.*

**Table 3**
**Fuel Outlets in Lucknow City**

| S.No. | Agency | Number of outlets as on 31st March 2017 |
|---|---|---|
| 1 | Indian Oil Corporation (IOC) | 51 |
| 2 | Bharat Petroleum Corporation Ltd. (BPCL) | 37 |
| 3 | Hindustan Petroleum Corporation Ltd. (HPCL) | 26 |
| 4 | Compressed Natural Gas Stations (CNG) | 9 |
| **Total** | | **123** |

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

**Table 4**
**Consumption of Fuel in Lucknow**

| S.N. | Agency | Petrol in KL | | | High Speed Diesel in KL | | | CNG in Kg | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Apr. 15 to Mar. 16 | Apr. 16 to Mar. 17 | % Change | Apr. 15 to Mar. 16 | Apr. 16 to Mar. 17 | % Change | Apr. 15 to Mar. 16 | Apr. 16 to Mar. 17 | % Change |
| 1 | **IOC** | 90507 | 103065 | 13.87 | 86101 | 91101 | 5.81 | -- | -- | -- |
| 2 | **BPCL** | 50570 | 54630 | 8.03 | 54990 | 55655 | 1.20 | --- | -- | -- |
| 3 | **HPCL** | 32540 | 35650 | 9.56 | 41390 | 83870 | 102.63 | --- | -- | -- |
| 4 | **Green Gas** | -- | -- | -- | -- | -- | -- | 30246000 | 32134736 | 6.24 |
| **Total** | | **173617** | **193345** | **11.36** | **182481** | **230626** | **26.38** | **30246000** | **32134736** | **6.24** |

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

**Table 5**
**Distribution of CNG vehicles**

| S.No. | Vehicles | Number | | % of Change |
|---|---|---|---|---|
| | | 2015-16* | 2016-17* | |
| 1 | Auto Rickshaws | 4343 | 4343 | -- |
| 2 | Tempo Taxi | 2575 | 2575 | -- |
| 3 | Buses (UPSRTC) | 260 | 260 | -- |
| 4 | Buses (Private) | 34 | 40 | -- |
| 5 | School Buses | 1099 | 1201 | 9.28 |
| 6 | School Van | 1404 | 1731 | 23.39 |
| 7 | Private Vehicles | 205 | 205 | -- |
| 8 | Private Cars | 9783 | 10851 | 10.92 |
| | Total | **19,703** | **21,206** | **7.63** |

*Source: RTO, Lucknow*

## 1.2 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 study as summarized in Table 6. Brief description of each location is given in our earlier reports (Pre and Post monsoon, 2010) and parameters along with methodology are given in Table 7.

**Table 6**
**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 7**
**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. | Trace Metals - (Pb & Ni) | 24 hours | AAS method after sampling on EPM 2000. |
| 6 | 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. |

## 1.3 RESULTS

The detailed results of air quality monitoring are presented in Table 8 and Figure1.

### 1.3.1 Respirable Suspended Particulate Matter (RSPM or $PM_{10}$)

In residential areas (Aliganj, Vikas Nagar, Indira Nagar and Gomti Nagar), the 24 hours average concentrations of $PM_{10}$ were in the range of 193.6 to 240.8 µg/$m^3$ with an average of 223.6 µg/$m^3$. In commercial areas (Charbagh, Alambagh, Aminabad and Chowk) the average concentrations of $PM_{10}$ were in the range of 189.2 to 310.6 µg/$m^3$ with an average of 234.7 µg/$m^3$ respectively. In industrial area (Amausi), the average concentration of $PM_{10}$ was 210.1 µg/$m^3$.

The maximum 24 hours mean concentration of $PM_{10}$ was observed in Indira Nagar (240.8 µg/$m^3$) in residential area and Chowk (310.6 µg/$m^3$) in commercial areas. All the values of $PM_{10}$ were above the prescribed National Ambient Air Quality Standard (NAAQS) of 100 µg/$m^3$ for industrial, residential, rural and other areas respectively.

### 1.3.2 Fine Particulate Matter ($PM_{2.5}$)

In residential areas (Aliganj, Vikas Nagar, Indira Nagar and Gomti Nagar), the 24 hours average concentrations of $PM_{2.5}$ were in the range of 93.4 to 124.1 µg/m$^3$ with an average of 107.5 µg/m$^3$. In commercial areas (Charbagh, Alambagh, Aminabad and Chowk) the average concentrations of $PM_{2,5}$ were in the range of 98.5 to 127.5 µg/m$^3$ with an average of 114.5 µg/m$^3$ respectively. In industrial area (Amausi), the average concentration of $PM_{2.5}$ was 106.3 µg/m$^3$.

The maximum 24 hours mean concentration of $PM_{2.5}$ was observed in Indira Nagar (124.1 µg/m$^3$) residential area and Chowk (127.5µg/m$^3$) in commercial area.

All the values of $PM_{2.5}$ were above the prescribed National Ambient Air Quality Standard (NAAQS) of 60 µg/m$^3$ for industrial, residential, rural and other areas.

### 1.3.3 Sub Fraction of Fine Particles ($PM_1$, $PM_{0.56}$, $PM_{0.32}$, $PM_{0.18}$, $PM_{0.1}$)

The monitoring of sub fractions of fine particles was conducted during the month of May, 2017 at two locations i.e. city commercial area (CSIR-IITR, Main Campus) and in rural area (CSIR-IITR, Gheru Campus) are reported in Table 9. The 24 hours mean mass concentrations of $PM_1$, $PM_{0.56}$, $PM_{0.32}$, $PM_{0.18}$ and $PM_{0.1}$ were found to be 27.02, 19.72, 16.35, 19.83 and 16.87 µg/m$^3$ respectively and total particulate level was 99.79 µg/m$^3$ in city commercial area. Similarly mass concentration in all the same fractions values for village/rural area were 13.44, 11.26, 13.49, 14.87 and 8.40 µg/m$^3$ respectively with total value was 61.46 µg/m$^3$. Average concentration of particulate matter in sub-fractions was higher in commercial area of Lucknow city as compared to rural area (Figure 2). For these particles, no International and National guideline is available at this point of time.

### 1.3.4 Sulphur Dioxide ($SO_2$)

In residential areas (Aliganj, Vikas Nagar, Indira Nagar and Gomti Nagar) the mean levels of $SO_2$ were in the range of 10.0 to 14.0 µg/$m^3$ with an average of 11.1 µg/$m^3$. In commercial areas (Charbagh, Alambagh, Aminabad and Chowk) the average concentrations of $SO_2$ were in the range of 10.9 to 13.5 µg/$m^3$ with an average of 11.8 µg/$m^3$. In industrial area (Amausi), the mean level of $SO_2$ was 12.2 µg/$m^3$.

All the values of $SO_2$ were well below the prescribed NAAQS of 80 µg/$m^3$ for all the locations.

### 1.3.5 Oxides of Nitrogen (NOx)

In residential areas (Aliganj, Vikas Nagar, Indira Nagar and Gomti Nagar) the 24 hours average concentrations of $NO_X$ were found in the range of 43.4 to 55.7 µg/$m^3$ with an average of 46.9 µg/$m^3$. In commercial areas (Charbagh, Alambagh, Aminabad and Chowk) the average concentrations of $NO_X$ were found in the range of 45.7 to 67.8 µg/$m^3$ with an average of 54.6 µg/$m^3$. In industrial areas (Amausi), the average concentration was 47.6 µg/$m^3$.

All the values of $NO_x$ were within the prescribed NAAQS of 80 µg/$m^3$ for all the monitoring locations.

**Table 8**
**Concentration (µg/m$^3$) of $PM_{10}$, $PM_{2.5}$, $SO_2$ and $NO_x$ during pre monsoon 2017**

| Location | $PM_{10}$ (RSPM) | | | $PM_{2.5}$ | | | $SO_2$ | | | NOx | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Residential** | | | | | | | | | | | | |
| | **Min** | **Max** | **Avg** | **Min** | **Max** | **Avg** | **Min** | **Max** | **Avg** | **Min** | **Max** | **Avg** |
| Aliganj | 163.7 | 280.3 | 228.7 | 93.1 | 129.4 | 103.9 | 7.1 | 13.4 | 10.1 | 29.9 | 64.4 | 48.4 |
| Vikas Nagar | 165.0 | 226.5 | 193.6 | 66.7 | 127.1 | 93.4 | 6.8 | 13.5 | 10.3 | 25.7 | 53.9 | 43.4 |
| Indira Nagar | 178.0 | 389.3 | 240.8 | 99.7 | 166.1 | 124.1 | 9.2 | 17.4 | 14.0 | 35.3 | 68.0 | 55.7 |
| Gomti Nagar | 173.4 | 298.4 | 231.4 | 90.6 | 132.2 | 108.4 | 8.5 | 11.5 | 10.0 | 31.2 | 55.8 | 40.2 |
| **Commercial** | | | | | | | | | | | | |
| Charbagh | 203.1 | 289.3 | 242.5 | 70.9 | 169.0 | 122.3 | 8.4 | 15.3 | 11.4 | 26.8 | 88.7 | 56.0 |
| Alambagh | 140.5 | 235.7 | 189.2 | 70.7 | 137.0 | 98.5 | 9.4 | 13.7 | 11.3 | 31.7 | 62.0 | 45.7 |
| Aminabad | 160.1 | 250.9 | 196.4 | 80.1 | 146.8 | 109.7 | 8.0 | 12.0 | 10.9 | 31.8 | 86.2 | 48.9 |
| Chowk | 178.1 | 373.3 | 310.6 | 92.3 | 158.5 | 127.5 | 9.0 | 16.7 | 13.5 | 40.8 | 97.8 | 67.8 |
| **Industrial** | | | | | | | | | | | | |
| Amausi | 170.4 | 241.2 | 210.1 | 80.5 | 132.0 | 106.3 | 9.0 | 16.7 | 12.2 | 28.1 | 61.1 | 47.6 |
| NAAQS | 100 | | | 60 | | | 80 | | | 80 | | |
| WHO Guidelines | 50 | | | 25 | | | 20* | | | 40* | | |

N=6, *= Annual Average, NAAQS=National Ambient Air Quality Standard

**Table 9**

**Mass concentration of Sub Fraction of Fine Particles (24 hours mean) during pre monsoon 2017**

| Sub-Fraction of Fine Particulates | City commercial area (CSIR-IITR M.G. Road Campus) | | | Rural area (CSIR-IITR Gheru Campus) | | |
|---|---|---|---|---|---|---|
| | Min. | Max. | Avg. | Min. | Max. | Avg. |
| $PM_{1.0}$ (≤1µm) | 25.09 | 28.10 | 27.02 | 13.24 | 13.91 | 13.44 |
| $PM_{0.56}$ (≤0.56µm) | 19.49 | 19.96 | 19.72 | 9.75 | 12.72 | 11.26 |
| $PM_{0.32}$ (≤0.32µm) | 15.27 | 17.36 | 16.35 | 11.55 | 15.40 | 13.49 |
| $PM_{0.18}$ (≤0.18µm) | 18.75 | 21.54 | 19.83 | 13.39 | 17.03 | 14.87 |
| $PM_{0.1}$ (≤100nm) | 15.45 | 18.60 | 16.87 | 6.83 | 10.20 | 8.40 |
| Total (fine) | 94.05 | 105.56 | 99.79 | 54.76 | 69.26 | 61.46 |

No. of samples = 3; Instrument used: MOUDI Cascade Impactor, USA

Micro Orifice Uniform Deposit (MOUDI) Cascade Impactor

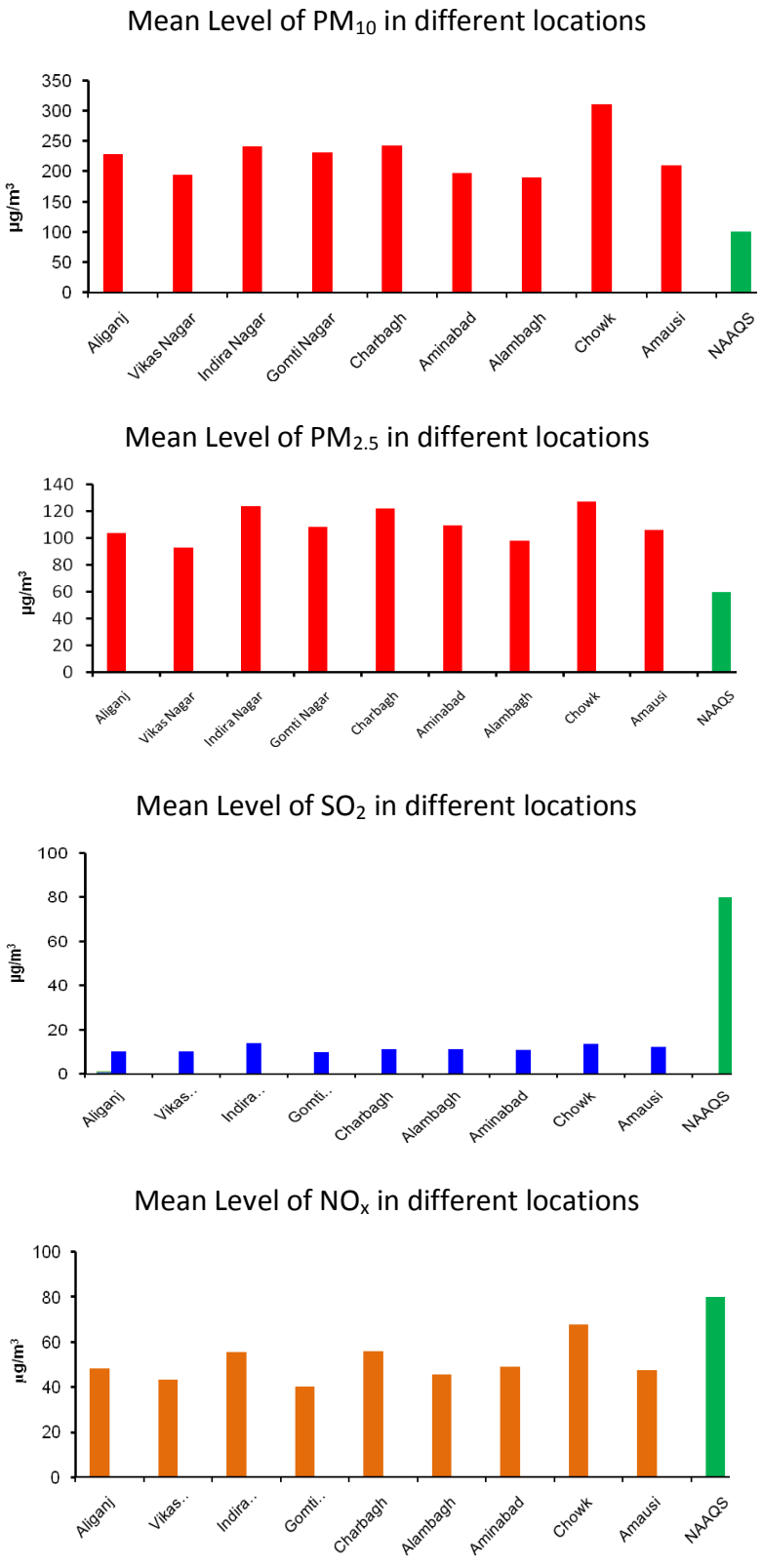



**Figure 1:** Concentration (µg/$m^3$) of $PM_{10}$, $PM_{2.5}$, $SO_2$ and $NO_x$ in different areas of Lucknow city during pre monsoon season (2017) and compared with prescribed National Ambient Air Quality Standard (NAAQS)

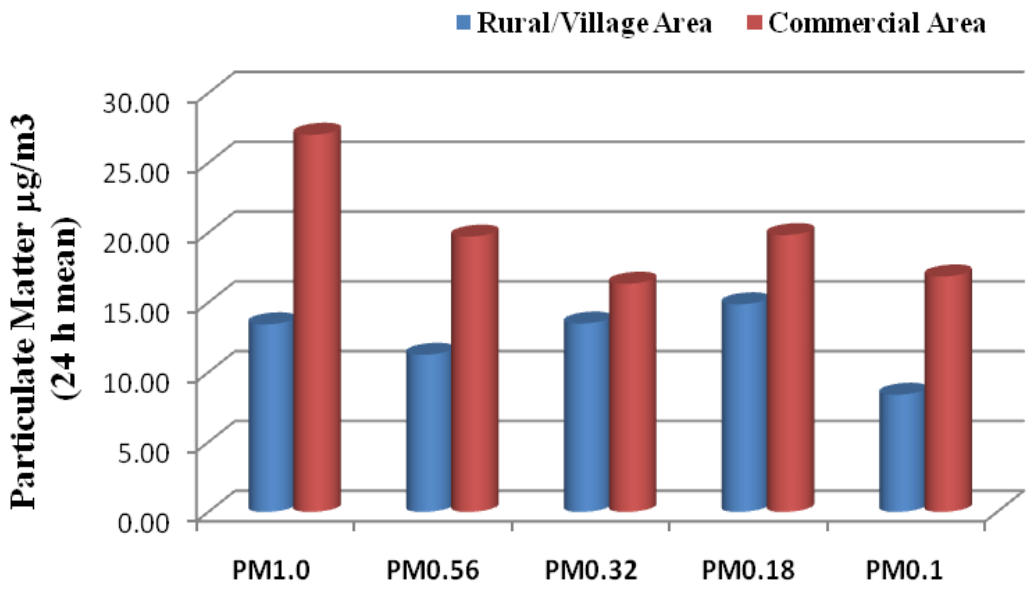



**Figure 2**: Pre-Monsoon levels of particulate matter in fine particle sub-fraction

### 1.3.6 Trace Metals in Ambient Air (RSPM)

The trace metals (Pb and Ni) were estimated in ambient air associated with $PM_{10}$ at 9 monitoring locations. The results are present in Table 10.

The 24 hr mean concentration of metals were found to be Pb = 219.97 (120.53 - 456.42) and Ni = 48.34 (32.52 – 81.97) ng/$m^3$. The mean level of Pb and Ni were found to be 76.65 and 22.35% increased over the previous year during pre monsoon.

**Table 10**
**Metal Concentration in ng/m$^3$ associated with $PM_{10}$**

| S.No. | Location | Lead(Pb) | Nickel (Ni) |
|---|---|---|---|
| 1 | Aliganj | 250.61 | 81.97 |
| 2 | Vikas Nagar | 137.42 | 51.48 |
| 3 | Indira Nagar | 120.53 | 32.52 |
| 4 | Gomti Nagar | 151.64 | 38.56 |
| 5 | Charbagh | 204.78 | 55.05 |
| 6 | Alambagh | 225.82 | 37.04 |
| 7 | Aminabad | 175.90 | 37.47 |
| 8 | Chowk | 256.58 | 54.19 |
| 9 | Amousi | 456.42 | 46.80 |
| **Mean** | | **219.97** | **48.34** |
| **NAAQS** | | **1000** | **20*** |

N= 1, *=Annual Average

### 1.3.7 Noise Level

The noise monitoring data recorded during the pre monsoon period (May, 2017) is presented in Table 11.

In residential areas, the day and night time noise levels were recorded between 65.8 to 72.1 and 56.3 to 63.3 dB(A) respectively. All the values were higher than the prescribed 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 between 75.2 to 81.4 and 58.0 to 67.4 dB(A) respectively. Noise level at all the commercial sites during day and night time were found above the prescribed limits of 65 and 55 dB (A) respectively. In industrial area Amausi, the day and night time noise levels were recorded 76.5 and 65.0 dB (A) respectively. Noise levels at industrial area during day and night time were recorded lower than the prescribed limits of 75.0 and 70.0 dB(A) respectively.

**Table 11**
**Noise Level dB (A) during Day and Night Time**

| S. No. | Area | Location | Noise level dB(A) | |
|---|---|---|---|---|
| | | | Day | Night |
| 1 | **Residential** | Aliganj | 65.8 | 62.5 |
| | | Vikas Nagar | 67.2 | 61.2 |
| | | Indira Nagar | 72.1 | 63.3 |
| | | Gomti Nagar | 70.5 | 56.3 |
| | | **Standard** | **55.0** | **45.0** |
| 2 | **Commercial** | Charbagh | 81.4 | 67.4 |
| | | Alambagh | 78.8 | 60.7 |
| | | Aminabad | 75.2 | 58.0 |
| | | Chowk | 76.8 | 66.8 |
| | | **Standard** | **65.0** | **55.0** |
| 3 | **Industrial** | Amausi | 74.5 | 65.0 |
| | | **Standard** | **75.0** | **70.0** |

## 1.4 TRENDS OF AMBIENT AIR QUALITY IN LUCKNOW CITY

The observed $PM_{10}$, $SO_2$ and $NO_x$ for 3 years data and $PM_{2.5}$ with last two year data have been compared to find out the prevailing trend of air pollution in Lucknow city (Figures 3-6). A slight change in the values may be attributed to some local environmental and climatic factors.

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

In the residential areas, comparatively higher values were found at all the residential areas, whereas higher values were also observed in two commercial areas (Charbagh and Chowk), whereas one industrial area showed lower value when compared to the data of the previous year. All the values are higher than the NAAQS (Figure 3).

### 1.4.2 Fine Particulate Matter ($PM_{2.5}$)

The level of $PM_{2.5}$ has been compared with the last year data and all the values of residential, commercial (except Alambagh and one Industrial areas) were found to be higher than the previous year. All the values of the present study were found to be higher than the NAAQS (Figure.4).

### 1.4.3 Sulphur dioxide ($SO_2$)

The level of $SO_2$ during pre monsoon since 2014 is presented in Figure 5 for all the locations. In residential areas, lower concentrations of $SO_2$ were found at all locations (except Indira Nagar) compared to that of the previous year. Among the commercial areas (except Chowk, $SO_2$ values showed slightly lower value over the last year. Industrial area (Amausi) also showed slightly higher value over the last year. All the values of the present study were found to be lower than the NAAQS (Figure 5).

### 1.4.4 Oxides of Nitrogen ($NO_x$)

The level of NOx during pre monsoon since 2014 is presented in Figure 5 for all the locations. Among the residential and commercial areas all the locations showed increasing trend, and the only industrial area Amausi also showed higher value when compared with the previous year data. All the values of the present study were found to be lower than the NAAQS (Figure 6).

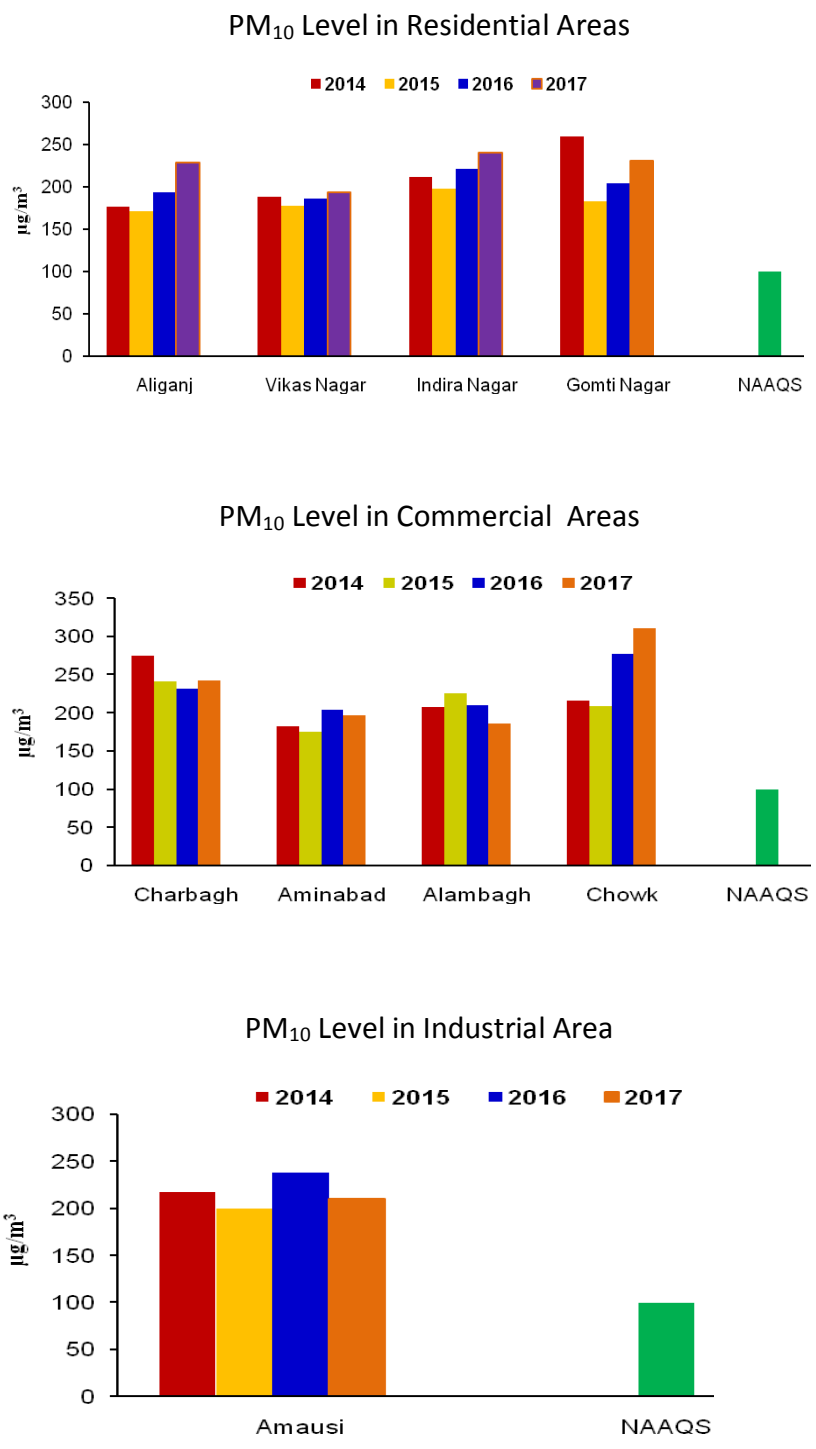



**Figure 3:** Concentration (µg/m$^3$) of $PM_{10}$ **(**RSPM**)** in Residential, Commercial and Industrial areas of Lucknow city during 2014 to 2017 and compared with prescribed National Ambient Air Quality Standard (NAAQS)

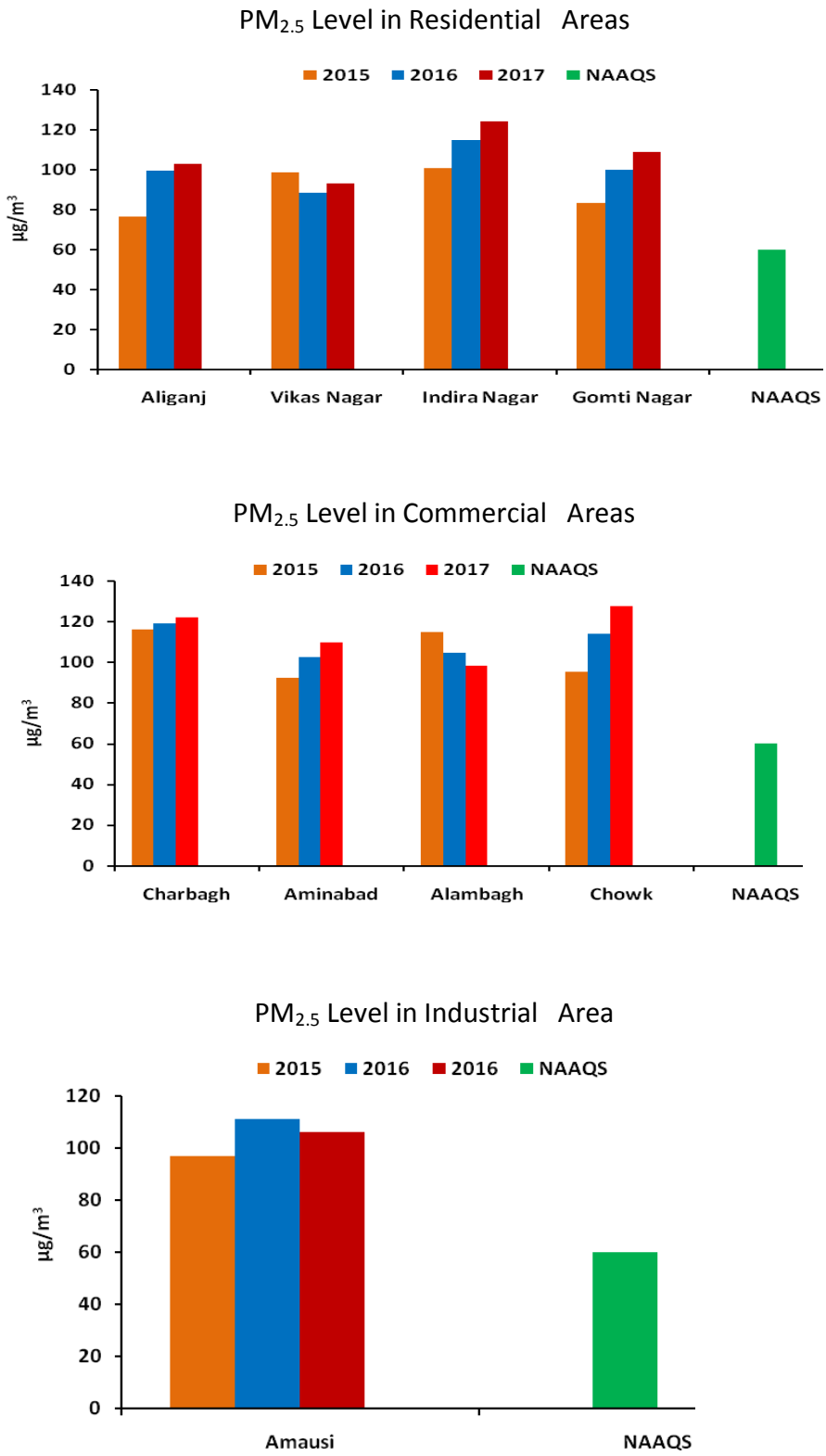
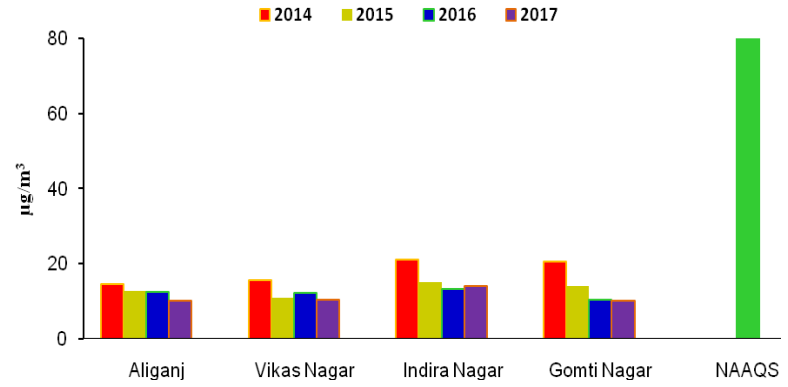
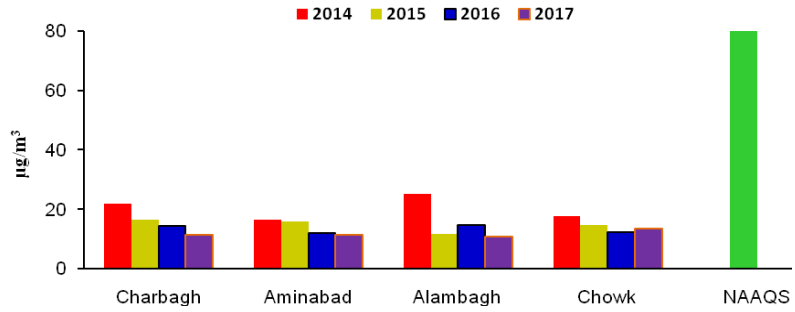



**Figure 4:** Concentration (µg/m$^3$) of $PM_{2.5}$ in Residential, Commercial and Industrial areas of Lucknow city during 2015 to 2017 and compared with prescribed National Ambient Air Quality Standard (NAAQS)

$SO_2$ Level in Residential Areas




$SO_2$ Level in Commercial Areas




$SO_2$ Level in Industrial Area

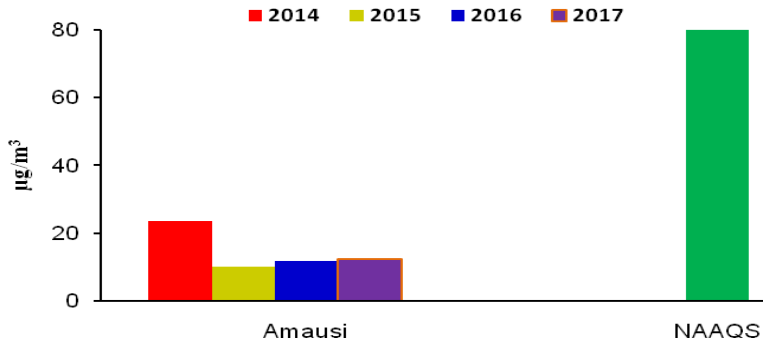



**Figure 5:** Concentration (µg/m$^3$) of $SO_2$ in Residential, Commercial and Industrial areas of Lucknow city during 2014 to 2017 and compared with prescribed National Ambient Air Quality Standard (NAAQS)

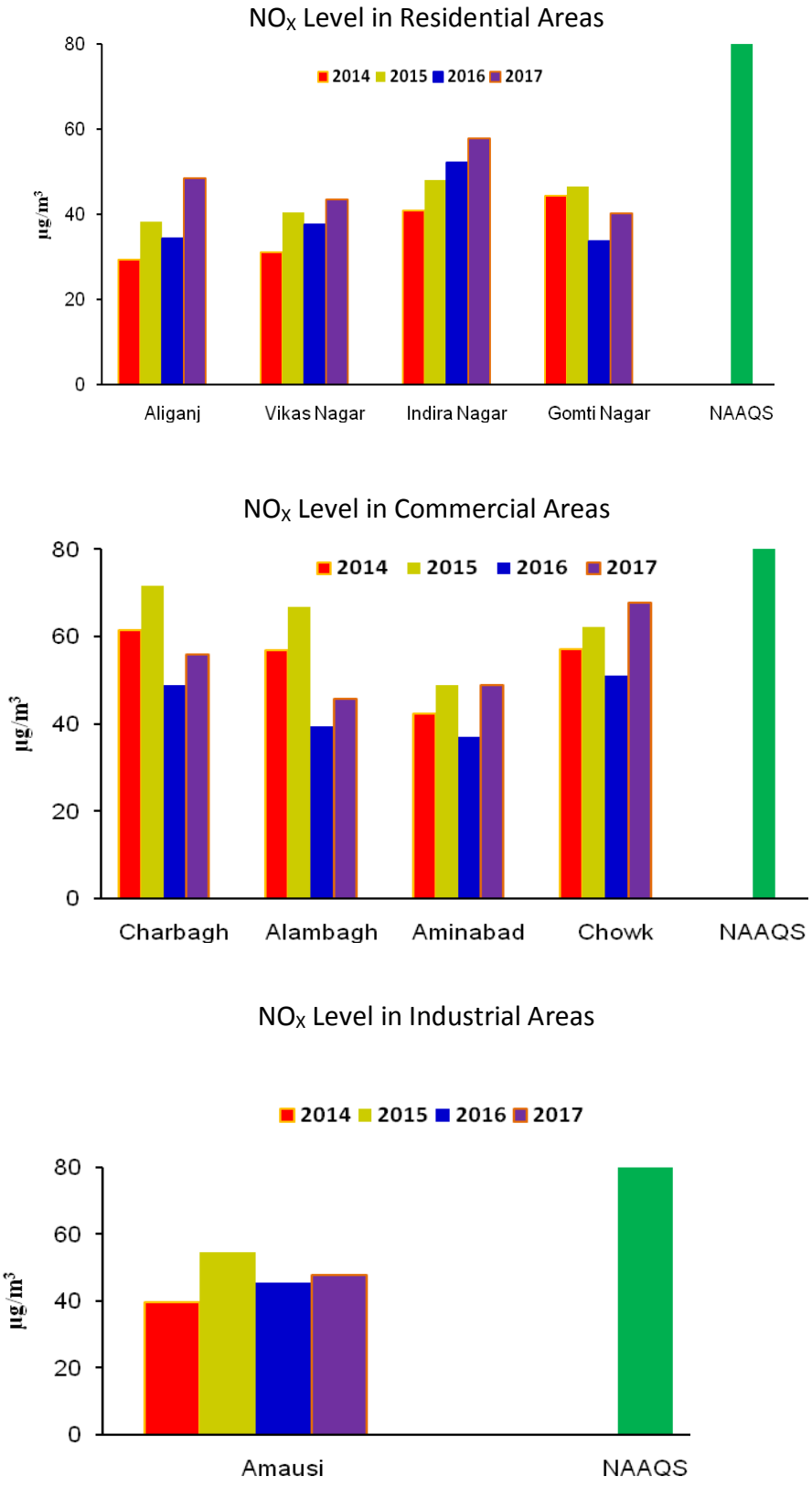



**Figure 6:** Concentration (µg/m$^3$) of $NO_x$ in Residential, Commercial and Industrial areas of Lucknow city during 2014 to 2017 and compared with prescribed National Ambient Air Quality Standard (NAAQS)

### 1.4.5 Noise Level

Current year's noise data was compared with the corresponding data of the previous three years (2014 to 2016 and presented in Figure 7 and 8. The comparative noise levels in residential, commercial and industrial areas are described below:

#### 1.4.5.1 Day time Noise Level

In residential areas, all the locations showed slightly decreasing trend over that of the previous year except Indira Nagar. In commercial cum traffic areas, noise level was found to be on the higher side at all the locations were recorded compared to that of previous year. In industrial area (Amausi) the noise level was slightly lower than that of the previous year. The comparative data are presented in Figure 7.

#### 1.4.5.2 Night time Noise Level

Residential areas showed slightly higher level than that of the last year except Gomti Nagar. In commercial areas, little variation in higher side was recorded at Aminabd and Chowk and the only industrial area showed slightly lower value than that of the previous year. The comparative data are presented in Figure 8.

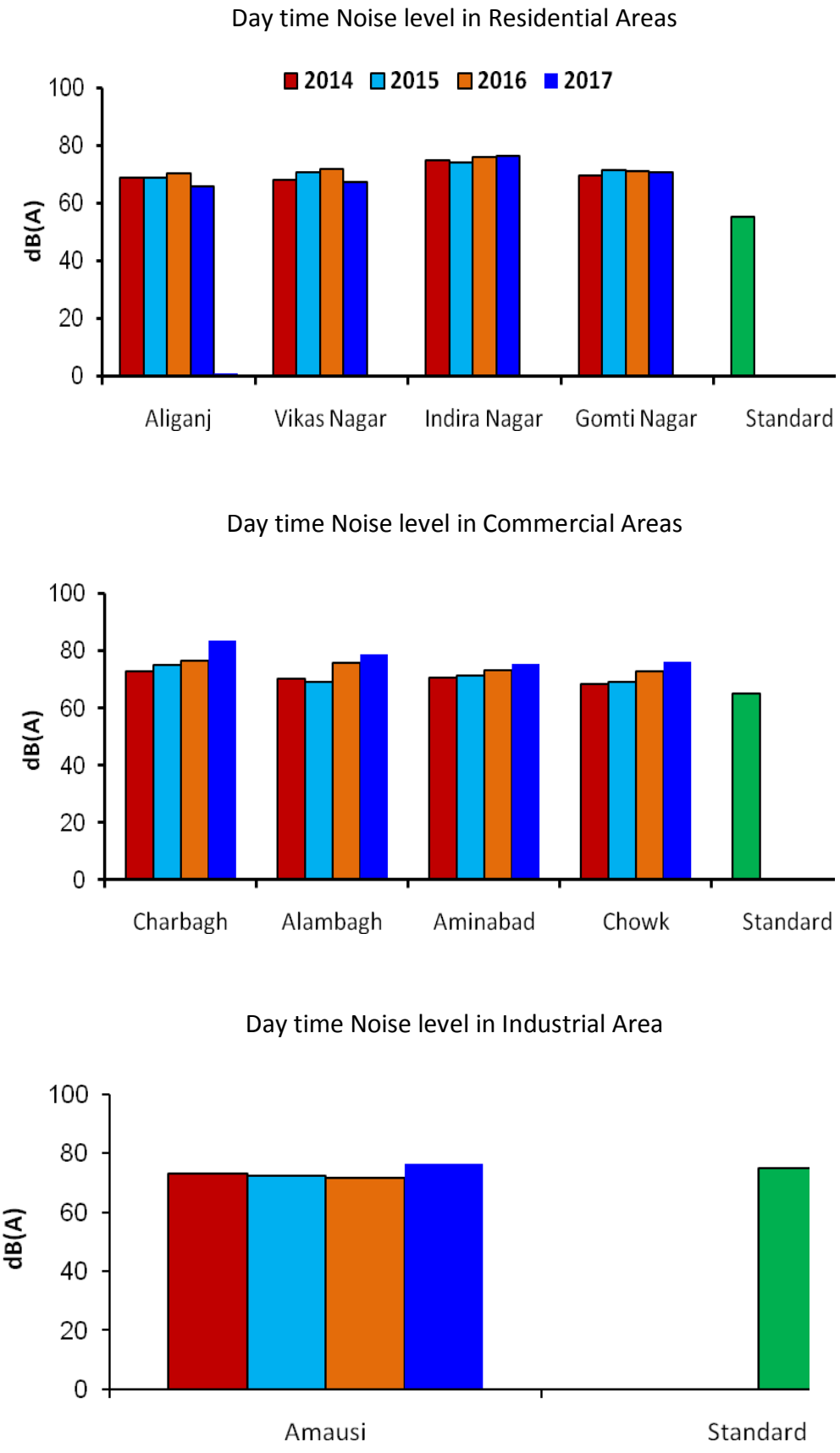
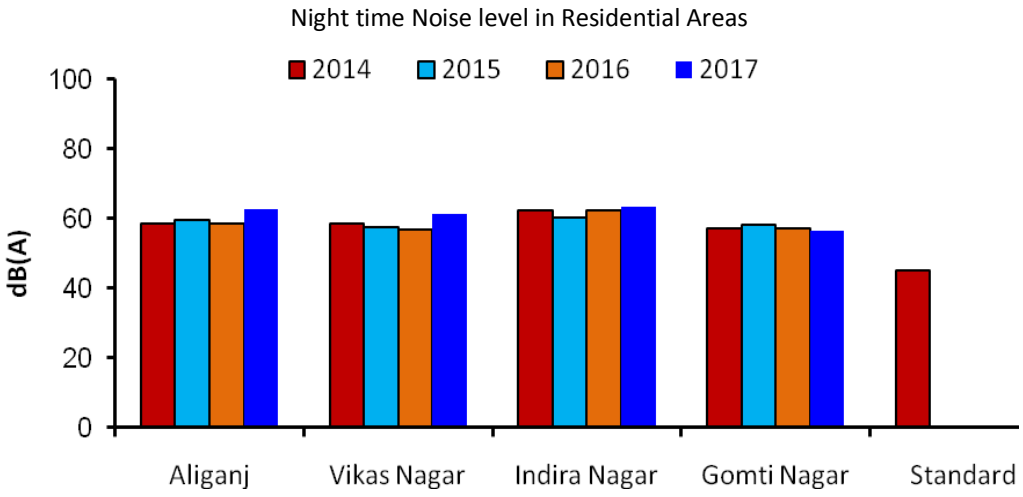
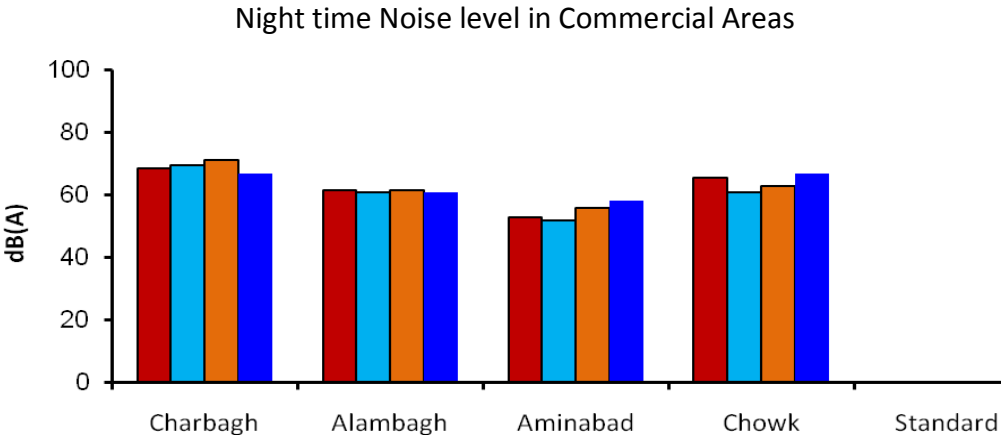



**Figure 7:** Comparison of day time Noise Level dB(A) in different areas of Lucknow city (2014-2017)



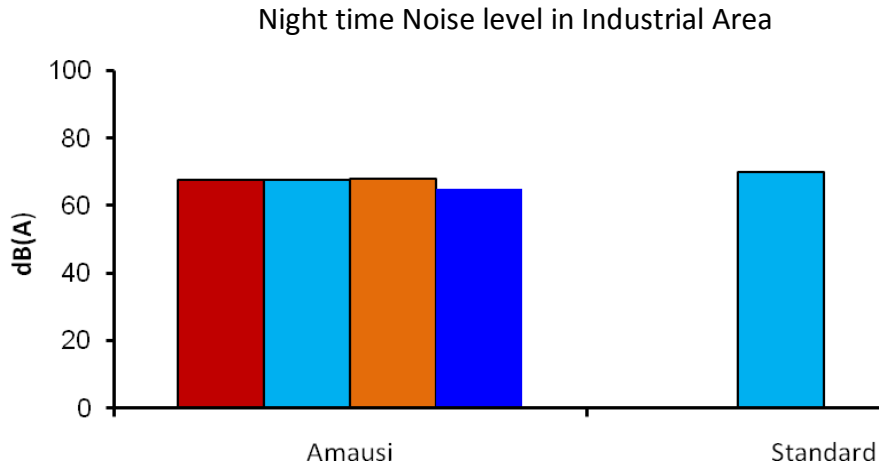




**Figure 8:** Comparison of night time Noise Level dB(A) in different areas of Lucknow city (2014-2017)

## 1.5 HEALTH EFFECTS

The air pollution levels for different pollutants are observed to be higher than the NAAQS-2009 in most of the Indian cities. The newly introduced indicator i.e. Air Quality Index was also recorded to be in the range of Poor (201-300), Very Poor (301-400) and Severe (>400) in various cities. Higher levels of air pollutants including metals have adverse effects on human and environmental health. Air Pollution creates series of significant health problems including (i) premature death (ii) aggravated asthma (iii) acute respiratory symptoms and (iv) decreased lung function in the form of shortness of breath and chronic bronchitis etc. Particulate matter is also a major cause of visibility impairment enhancing coefficient of haze in many parts of Asian countries and United States because these particles can scatter and absorb light. Further fine particles can remain suspended in air and travel long distances across regional and international borders without sinking and settling. Numerous epidemiological studies indicate that an increase in particulate matter concentration is associated with increased mortality, increased hospitalization for respiratory and cardio vascular diseases increased respiratory symptoms and decreased lung functions.

Sulphur Dioxide ($SO_2$) is a colorless water-soluble gas and smells like burnt matches. It can be oxidized to sulphur trioxide, which in the presence of water vapor is readily transformed to sulphuric acid mist. Oxides of Nitrogen ($NO_x$) causes a wide variety of health and environmental impacts because of various compounds and derivatives in the family of nitrogen oxides, including nitrogen dioxide, nitric acid, nitrous oxide, nitrates, and nitric oxide. $NO_2$ is a reddish-brown gas with a pungent and irritating odour. It transforms in the air to form gaseous nitric acid and toxic organic nitrates. Nitrogen dioxide can have both acute and chronic effects on health, particularly in people with asthma. $NO_2$ causes inflammation of the airways.

Elevated levels of noise have adverse effects varying from hearing loss to annoyance. Annoyance and psychological damage would occur at much lower noise levels. The

inorganic components constitute a small portion by mass of the particulates; the high level of Pb can induce severe neurological and hematological effects on the exposed population especially children. Details of pollutants effects are given below.

### 1.5.1 Health Effects of Particulate Matter ($PM_{10}$ & $PM_{2.5}$)

Particulate Matter has a diameter ≤ 10 µm and diameter ≤ 2.5 µm when inhaled would penetrate beyond the larynx.

- Small particles penetrate deeply into the lung and can cause respiratory disease such as emphysema and bronchitis, and aggravate existing heart disease.
- Ultra fine particles ranging from 0.001 to 0.1 micron in diameter are able to penetrate deep into the lung and to the alveolar sacs where gaseous exchange occurs.
- Further these particles increase the rates of blood flow and vascular permeability to white blood cells, elevating clotting activity, constriction of the airways and fever induction.

### 1.5.2 Health Effects of Sulfur Dioxide ($SO_2$)

Elevated value of $SO_2$ may cause- irritation of the eyes, nose and throat, choking and coughing.

- Reflex cough, irritation, and a feeling of chest tightness, which may lead to narrowing of the airways, particularly likely to occur in people suffering from asthma and chronic lung disease, whose airways are often inflamed and easily irritated.
- Oral inhalation of larger volumes may reach the segmental bronchi and damage the organ and exposure of the eyes (eg. in an industrial accident) can cause severe burns and resulting in the loss of vision.
- Repeated or prolonged exposure to moderate concentrations may cause inflammation of the respiratory tract, wheezing and lung damage other health effects include headache, general discomfort and anxiety.

### 1.5.3 Health Effects of Oxides of Nitrogen ($NO_x$)

NOx causes a wide variety of health and environmental impacts because of various compounds and derivatives in the family of NOx including $NO_2$, $HNO_3$, NO, nitrates and nitric oxide.

- Nitrogen dioxide ($NO_2$) is associated with mortality and a range of morbidity outcomes.
- $NO_2$ can be used as a marker of traffic proximity and convenient metric for modelling the health impacts of traffic pollution and evaluating abatement policies.
- Long term exposure to $NO_2$ may affect lung function and lowering the resistance to diseases such as pneumonia and influenza.
- Extremely high-dose exposure (as in a building fire) to $NO_2$ may result in pulmonary edema, diffuse lung injury and development of acute or chronic bronchitis.
- Industrial exposures to nitric oxide can cause unconsciousness, vomiting, mental confusion, and damage to the teeth.
- Exposure to low levels of nitrogen oxides in smog can irritate the eyes, nose, throat and lungs and can cause coughing, shortness of breath, fatigue, and nausea.

### 1.5.4 Health Effects of Noise Pollution

Elevated Noise levels of ambient air may have cause adverse health effects.

- Noise produces both temporary and permanent hearing loss.
- Noise can range from the bursting of the eardrum to permanent hearing loss, cardiac, cardiovascular changes, stress, fatigue, dizziness and lack of concentration.
- Continuous noise causes an increase in cholesterol level resulting in constriction of blood vessels making prone to heart attack and stress.

### 1.5.5 Health Effects of Trace Element (metals)

Metals or trace element (Pb & Ni) which are bind to inhalable particulate fraction ($PM_{10}$ & $PM_{2.5}$) easily bind to cell membrane.

- Trace metals absorbed in human body through inhalation eventually reach target organs viz brain, liver, blood, reproductive organ or any other system.
- High levels of Pb can induce severe neurological and hematological effects on the exposed population especially children, whereas Ni is known for inducing carcinogenic effects in human through inhalation.

In the present study, the concentration of $SO_2$ and NOx were found to be below permissible limit (80 µg/$m^3$) of NAAQS (MoEF 2009), but there are several reports suggesting that gaseous pollutants are related with respiratory diseases and reproductive and developmental effect even at low concentrations. Vehicular traffic and $NO_2$ are associated with significantly higher risk of lung cancer.

## 1.6 CONCLUSIONS

During pre monsoon (April-May), 2017 we have monitored air pollutants such as $PM_{10}$, $PM_{2.5}$, $SO_2$, $NO_x$ and trace metals for the assessment of ambient air quality. Besides, we have also monitored noise level during day and night time at 9 locations. The results revealed as follows-

- The RSPM ($PM_{10}$) level at all the monitoring locations of residential, commercial and industrial areas were higher than the NAAQS.
- The mean level of Fine particles ($PM_{2.5}$) at all the monitoring locations of residential, commercial and industrial areas was higher than the NAAQS.

- The monitoring values of sub fractions of particles were found to be higher in commercial place. Presently there is no guideline/NAAQS for these sub-fractions fine particles. There is considerable toxicological evidence of potential detrimental effects of these sub-fraction particles on human health.

- The concentration of gaseous pollutants, $SO_2$ and $NO_x$ were below the prescribed NAAQS (80 µg/$m^3$) at all the locations but showed slightly lower values compared to previous year with little exception. The lower values especially in the Alambagh, Charbagh areas might be due to low volume to heavy traffic on the metro construction route than the previous years.

- The noise level at all the locations except in industrial area during day and night time showed higher level than their respective permissible limits.

- Overall results indicate that $PM_{10}$ and $PM_{2.5}$ showed increasing trend and associated metals are one of the major causes for deterioration of ambient air quality.

- Elevated levels of air pollutants and their effects on human health is a serious issue. To resolve the issue, comprehensive studies is required of in respect of present status of different pollutants and their trends, sources of pollutants, public health risk assessment for future planning urban areas.

- Regulatory authorities, National Institute, academicians and NGOs should take this issue seriously with authentic research, formation of viable rules and their proper implementation as well as mass awareness amongst public.

## 1.7 RECOMMENDATIONS FOR MITIGATION OF AIR POLLUTION

1. Major roads of the city should be widened as far as possible.
2. Suitable modification on crossing for smooth traffic flow.
3. Encroachments be removed for smooth flow of traffic.
4. Restore foot path for pedestrians.
5. Provision of parking facilities by private operators on vacant private land.
6. Government should increase the parking charges on hourly basis to discourage the use of personal vehicles in congested areas.
7. Subsidized public mass transport (Metro, Monorail etc.) must be introduced/ strengthened to minimize use of personal vehicles.
8. Improvement in traffic management.
9. Public awareness programme of air pollution and its health effects, reduction of automobile pollution by proper maintenance of vehicles, driving skills.
10. Systematically develop residential complex at the periphery of the city with all facilities to reduce crowd from central areas of the city.
11. Provision of bus stands on all the outgoing highways to reduce traffic load inside city.
12. Removal of garbage dumps along the roads.
13. Ban on burning of dry leaves, tyres or any other type of solid waste and arrangement for its proper disposal.
14. Plantation of trees wherever possible in parks, open spaces and road side areas.
15. Installation of more CNG filling stations across the city.
16. Encouragement for battery operated or hybrid vehicle.
17. Promoting solar energy as an alternate to D.G. sets.
18. Pressure horns to be removed from all vehicles and avoid/ minimize use of horn.

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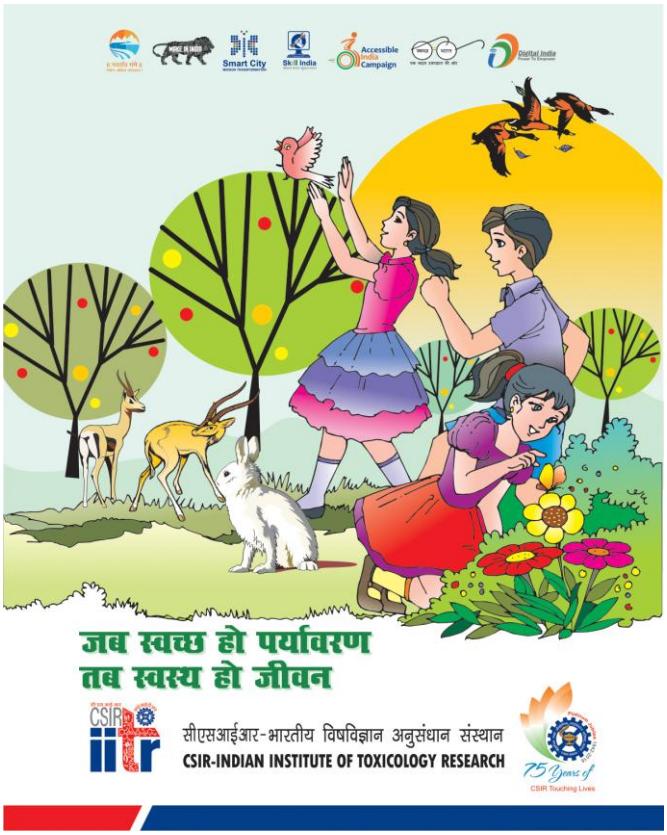
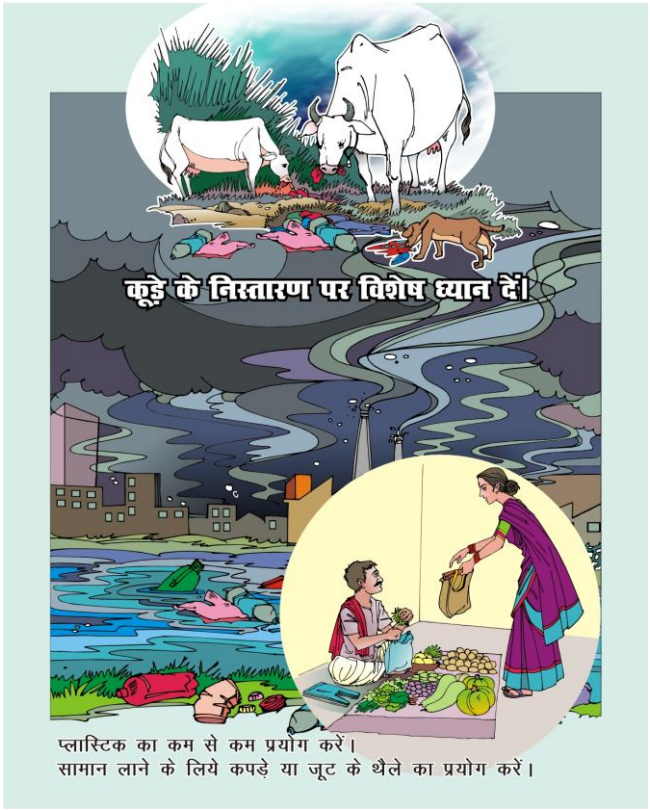
## Annexure: 1 Skill Development

Ambient Air and Stack Monitoring Technique: Hands-on-Training


Annexure 2: Brochure – Public Awareness for Clean Environment





कूड़े के निस्तारण पर विशेष ध्यान दें।
प्लास्टिक का कम से कम प्रयोग करें।
सामान लाने के लिये कपड़े या जूट के थैले का प्रयोग करें।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