# ASSESSMENT OF AMBIENT AIR QUALITY OF LUCKNOW CITY

## POST-MONSOON 2015

## FINDINGS OF A RANDOM SURVEY

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**CSIR-INDIAN INSTITUTE OF TOXICOLOGY RESEARCH**

विषविज्ञान भवन, 31, महात्मा गाँधी मार्ग, पोस्ट बाक्स नं० 80, लखनऊ-226001, उ.प्र., भारत

VISHVIGYAN BHAWAN, 31, MAHATMA GANDHI MARG, POST BOX NO 80, LUCKNOW-226001, U.P. INDIA

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## (POST- MONSOON 2015)

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# PERSONNEL

| | | |
|---|---|---|
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# Salient Features of the Study

| | | |
|---|---|---|
| ❖ **Geographical Position** | **:** | $26^o$ 52' N Latitude<br>$80^o$ 56' E Longitude<br>128 m above Sea Level |
| ❖ **Area** | **:** | 310 sq. km. |
| ❖ **Population** | **:** | 28,15033 as per 2011 Census |
| ❖ **Projected Population** | **:** | 45 lakh as per *Master Plan 2021* |
| ❖ **Climate** | **:** | Subtropical climate, cool dry winter (Dec.- Feb.) & summer (Mar - Jun.). Temperature about $45^0$C in summer to $3^0$C in winter. Average annual rainfall about 100 cm. |
| ❖ **Total Vehicular Population In Lucknow city as on 31/03/2015** | **:** | 17,09,662 |
| ❖ **Growth of Vehicle over 2013-2014** | **:** | 10.08% |
| ❖ **Total No. of Filling Stations (Petrol/Diesel/CNG)** | **:** | 101 |
| ❖ **Consumption of Petrol** | **:** | 1,49,281 KL |
| ❖ **Consumption of Diesel** | **:** | 1,58,534 KL |
| ❖ **Consumption of CNG** | **:** | 2,77,40,909 Kg |
| ❖ **Major Sources of Pollution** | **:** | Automobiles, D. G. sets, Civil Constructions |
| ❖ **Parameters Monitored** | **:** | $PM_{10}$, $PM_{2.5}$, Superfine , Ultrafine, $SO_2$, $NO_X$, trace metals and noise level. |
| ❖ **Study Conducted by** | **:** | Environmental Monitoring Division & Inhalation Toxicology Division CSIR- IITR, Lucknow |

**ASSESSMENT OF AMBIENT AIR QUALITY OF LUCKNOW CITY DURING POST-MONSOON, 2015**

**Environmental Monitoring Division & Inhalation Toxicology Division**
**CSIR- Indian Institute of Toxicology Research**
**M.G. Marg, Lucknow**

## 1.0 SUMMARY

*The study was carried out during the months of September-October, 2015 to assess the status of air quality of Lucknow city by monitoring and assessment of some selected air pollutants namely Respirable 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 levels 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 132.2 to 349.8 $\mu g/m^3$ with an average of 218.9 $\mu g/m^3$. The 24 hours concentration of $PM_{2.5}$ was found to be in the range of 63.3 to 159.7$\mu g/m^3$ with an average of 108.2 $\mu g/m^3$.The average values of $PM_{10}$ and $PM_{2.5}$ irrespective of locations were found to be above the permissible limit (100 $\mu g/m^3$ for $PM_{10}$ and 60 $\mu g/m^3$ for $PM_{2.5}$ prescribed by MoEF). For the first time, monitoring of superfine and ultrafine particles was carried out. 24 hours mean concentration of superfine particles $PM_{0.56}$ = 5.67 to 17.98, $PM_{0.32}$ = 6.84 to 12.2 and $PM_{0.18}$ = 3.56 to 12.76 $\mu g/m^3$ and ultrafine particles were found to be in the range of 4.32 to 9.54 $\mu g/m^3$ for $PM_{0.10}$ and 2.85 to 9.87 $\mu g/m^3$ for $PM_{0.056}$. Till date there is no permissible limit recommended for superfine and ultrafine particles by the concerned authority in India. 24 hours concentration of $SO_2$ and NOx were found to be in the range of 11.6 to 28.5 and 42.1 to 89.4 $\mu g/m^3$ with an average concentration of 20.1 and 67.2 $\mu g/m^3$ respectively and all the values were below the permissible limits (80 $\mu g/m^3$). The mean level of trace metals were* Ni = *18.86 and Pb = 135.64* ng/$m^3$. *Noise levels during day and night time were found to be in the range of 64.6 to 75.5 dB (A) and 53.1 to 70.2 dB (A) respectively which was above the respective permissible limits except in the industrial area.*

## 1.1 INTRODUCTION

Air pollution as well as climate change are the serious issues that world environmentalists are concerned about today. Policy makers as well as the regulatory bodies of individual countries have agreed upon its serious consequences. Quantitatively, there is a marked difference regarding the per capita air pollutants emission among the developed, developing and underdeveloped countries. Growth is necessary, which is directly related with energy as well as the fossil fuel consumption. Underdeveloped countries are now focusing more on development and using more fossil fuels for their energy needs. All the issues are now more debatable for policy makers who ultimately need to focus on sustainable development and need to rethink about the proper meaning of the terminology i.e., growth, development, progress with respect to our environment and society.

Now-a-days, economic development has changed our socio-economic scenario especially in urban areas and one of the important changes is that the people are more dependent on individual conveyance. Further, lack of proper mass transport system, has resulted in vigorous growth of vehicular population and as a result there are more air pollutants in the ambient air. People are now-a-days more conscious and concerned because their health is being affected due to air pollutants.

There are a number of scientific reports suggesting that there is a direct correlation of vehicular air pollution due to burning of fossil fuel i.e petrol, diesel, CNG, LPG etc. and human health effects especially in urban areas. Burning of multiple fuels in different proportions aggravate the pollution scenario with respect to chemical composition and nature of pollution. Recent research fuels the debate about green fuel as well as safe fuel. Whatever fuels are in use, it may create worst scenario in the long run because increase of volume leads to a change of air quality and adversely affects health of exposed people. Besides tail pipe emission as well as vehicular pollution, there are other sources of air pollution such as operation of gensets, industrial emission, burning of solid waste, etc.

Lucknow, the capital of Uttar Pradesh is a fast growing city. To meet the needs of this rapid growth, Lucknow Development Authority (LDA) has prepared a

master plan for 2031. This master plan has been prepared for the projected population of about 80 lakh expected in the coming 16 years. About 197 villages around the city will become a part of Lucknow in this plan. The most important feature of the 2031 master plan is a 105 km long outer ring road. The development of newly included areas is envisaged in the field of education, health, security, power supply, telephone exchange and other services. This massive development will result in the influx of more people with more vehicles in the city.

Over the last decade the rate of vehicular population was near about 10%. In the coming years, vehicular growth is expected to increase. As Per RTO data, city had 17,09,662 registered vehicles till March 2015. The consumption of fuel by vehicles during 2014-2015 for diesel was 1,58,534 KL, petrol 1,49,281 KL and that of CNG was 2,77,40,909 KG. The consumption of these fuels is 7.6, 2.13 and 5.66% higher over the previous year for petrol, diesel and CNG respectively. Initially public transport buses and tempos/auto rickshaws were converted to CNG and thereafter all school buses and subsequently the number of private cars fitted with CNG has also increased. Recently, State Transport department has issued an order to use only CNG vehicles for public transport.

The vehicular growth is expected to be higher to meet the demand of transport activity in the city in future. Also with enforcement of CNG use, CNG vehicles will also increase. Moreover, there is an increasing awareness in our citizens towards the cleaner fuel use of CNG/LPG in private vehicles. The new generation vehicles have efficient engines that are economical in fuel consumption per km travel. The better combustion efficiency of the engines, leads to the emission of more finer particles in ambient air. A study carried by CSIR-Indian Institute of Petroleum, Dehradun on CNG buses in Delhi found that, “nano carbon particles” are coming out of the exhaust of the CNG buses. These carbon nano particles are not visible to the naked eye, unlike the exhaust fumes from a diesel vehicle. With more and more CNG vehicles on road, more carbon nano particles will be floating in the ambient air. These nano particles can enter straight through the nose and lungs as the separation mechanism of human respiratory system is able to stop the entry of size of micron range particles only. Once entered into the lungs, these nano particles can penetrate through the membranes right into the blood stream. Nano particles provide a large surface area per

unit volume and may contain various toxic chemicals such as polynuclear aromatic hydrocarbon and trace metals, therefore the health impacts of nano particles is also needs to be studied.

Keeping this in mind we carried out air monitoring to evaluate the air quality with respect to major pollutants like PM ($PM_{10}$, $PM_{2.5}$), $SO_2$, NOx, trace metals and noise levels of Lucknow city during post monsoon, 2015 as we did, every year since 1997. For the first time monitoring of superfine and ultrafine particles was also carried out in the city. The study was carried out with the following aims and objectives:

- *To assess the ambient air quality with respect to $PM_{10}$, $PM_{2.5}$, $PM_{0.56}$, $PM_{0.32}$, $PM_{0.18}$, $PM_{0.1}$ and $PM_{0.056}$, $SO_2$, 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 to ensure compliance of permissible noise levels.*
- *To create a database for future use.*
- *To create public awareness about environmental pollution.*

**Table 1. Vehicles Registered with R.T.O. Lucknow during 2013-14 and 2014-15**

| Sl. No. | Type of Vehicle | Number of Registered Vehicles on 31st March | | % Change |
|---|---|---|---|---|
| | | 2013-14 | 2014-15 | |
| 1 | Multi Articulated | 2974 | 3514 | 18.15 |
| 2 | Light, Medium and Heavy weight Vehicles (Four wheeler) | 18430 | 20930 | 13.56 |
| 3 | Light commercial vehicles (Three wheeler) | 3225 | 3413 | 5.82 |
| 4 | Buses | 3249 | 3306 | 1.7 |
| 5 | Taxi | 7797 | 9153 | 17.39 |
| 6 | Light Motor Vehicles (Passenger) | 7743 | 7562 | -2.3 |
| 7 | Two wheelers | 1238691 | 1361787 | 9.9 |
| 8 | Car | 221019 | 244121 | 10.45 |
| 9 | Jeep | 22175 | 26019 | 17.33 |
| 10 | Tractor | 22010 | 23679 | 7.58 |
| 11 | Trailers | 1469 | 1580 | 7.55 |
| 12 | Others | 4283 | 4598 | 7.35 |
| Total | | **1553065** | **1709662** | **10.08** |

*Source: RTO, Lucknow*

**Table 2. Details of Lucknow City Bus Service, 2015**

| Sl. No. | Route No. | To and Fro | No. of Buses | Frequency |
|---|---|---|---|---|
| 1 | 11 | BBD -Chinhat-Gomti Nagar-Alambagh | 18 | 10 minutes interval |
| | | Malhaur railway station-Gomtinagar-Dalibagh-Charbagh | | |
| | | Charbagh-Alambagh-Avadh hospital-SGPGI | | |
| | | Charbagh- Alambagh -Sardar Patel Dental college | | |
| | | BBD-Chinhat- Avadh hospital | | |
| | | Charbagh- Alambagh- BBAU | | |
| | | Charbagh-Alambagh- Gopesh Kunj-Kalindi Park | | |
| | | Khargapur-Patrakarpuram-Alambagh | | |
| 2 | 12 | BBD- Chinhat- Charbagh- Alambagh-Scooter India<br>Samarpan college- Chinhat-Charbagh- Alambagh- Scooter India<br>BBD-Charbagh- Alambagh- Paasi Kila | 16 | 15 minutes interval |
| 3 | 13 | Charbagh –Mobaiya-Alambagh thana-Teri Phulia-Alambagh-bus stand-Awadh Hospital-Krishnanar thana-Natherganj – Scooter India-Koti Bagia. | 06 | 12 minutes interval |
| 3 | 23 | Gudamba – Vikasnagar- Alambagh- Rajnikhand | 22 | 10 minutes interval |
| | | Gudamba –Badshanagar – Avadh hospital | | |
| 4 | 24 | Engineering College-Indiranagar-Charbagh-Alambagh-Paasi Kila | 10 | 15 minutes interval |
| | | Manas Bihar colony- Scooter India | | |
| | | Munshipulia- Alambagh-Kasiram Yojna-Avadh hospital | | |
| 6 | 31 | Alambagh – IIM | 02 | 60 minutes interval |
| 7 | 33 | Engineering College-Charbagh-Alambagh-Scooter India | 16 | 10 minutes interval |
| 8 | 45 | Virajkhand-Gomtinagar-Charbagh-Alambagh-Paasi Kila | 17 | 15 minutes interval |
| | | Total | 107 | |

*Source: Lucknow City Transport Services Limited.*

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

| Sl. No. | Agency | Number of outlets |
|---|---|---|
| | | **31st March 2015** |
| 1 | Indian Oil Corporation (IOC) | 48 |
| 2 | Bharat Petroleum Corporation Ltd. (BPCL) | 22 |
| 3 | Hindustan Petroleum Corporation Ltd. (HPCL) | 25 |
| 4 | Compressed Natural Gas Stations (CNG) | 6 |
| | **Total** | **101** |

*Source: Indian Oil Corporation (IOC), Lucknow*

**Table 4. Consumption of Fuel (in KL) in Lucknow**

| Sl. No. | Agency | Petrol in KL | | | High Speed Diesel in KL | | | *CNG in Kg | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Apr. 13 to Mar. 14 | Apr. 14 to Mar. 15 | % Change | Apr. 13 to Mar. 14 | Apr. 14 to Mar. 15 | % Change | Apr. 13 to Mar. 14 | Apr. 14 to Mar. 15 | % Change |
| 1 | IOC | 77693 | 82951 | 6.80 | 88234 | 86092 | -2.40 | --- | | |
| 2 | BPCL | 34178 | 37673 | 8.10 | 31497 | 34179 | 10.10 | --- | | |
| 3 | HPCL | 26884 | 28657 | 9.20 | 35495 | 38263 | 6.40 | --- | | |
| 4 | Green Gas | -- | | | -- | | -- | 26255742 | 27740909 | 5.65 |
| **Total** | | **138755** | **149281** | **7.60** | **155226** | **158534** | **2.13** | **26255742** | **27740909** | **5.66** |

*Source: Indian Oil Corporation (IOC), Lucknow, * CNG Source: Green Gas Limited, Lucknow*

**Table 5. Distribution of CNG vehicles**

| Sl. No. | Vehicles | Number | | % of change |
|---|---|---|---|---|
| | | 2013-14 | 2014-15 | |
| 1 | Auto Rickshaws | 4343 | 4343 | 0 |
| 2 | Tempo Taxi | 2575 | 2575 | 0 |
| 3 | Buses (UPSRTC) | 260 | 262 | 7.69 |
| 4 | Buses (Private) | 36 | 34 | -5.55 |
| 5 | School Buses | 985 | 1033 | 4.87 |
| 6 | School Van | 962 | 1154 | 19.95 |
| 7 | Private Vehicles | 205 | 258 | 25.85 |
| 8 | Private Cars | 7943 | 8940 | 12.55 |
| | Total | **17309** | **18599** | **7.45** |

*Source: Green Gas Limited and 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**

| Sl . 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. | Superfine (0.18 to 0.56 µm)<br>Ultrafine (0.056 to 0.10 µm) | 24 hours | Gravimetric Ten stage MOUDI Impactor |
| 4 | Sulphur dioxide ($SO_2$) | 24 hours | Improved West Gaeke |
| 5 | Nitrogen Dioxide($NO_2$) | 24 hours | Modified Jacob & Hochhesier (Na-Arsenite) |
| 6. | Trace Metals -<br>(Pb & Ni) | 24 hours | AAS analysis after sampling on EPM 2000 and acid digestion. |
| 7 | 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 Fig. 1.

### 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 180.4 to 218.2 $\mu g/m^3$ with an average of 195.2 $\mu g/m^3$. In commercial areas (Charbagh, Alambagh, Aminabad and Chowk) the average concentrations of $PM_{10}$ were in the range of 215.5 to 264.9 $\mu g/m^3$ with an average of 243.8 $\mu g/m^3$ respectively. In industrial area (Amausi), the average concentrations of $PM_{10}$ was 214.2 $\mu g/m^3$.

The maximum 24 hours mean concentration of $PM_{10}$ was observed in Indira Nagar (218.2 $\mu g/m^3$) in residential area and Alambagh (264.9 $\mu g/m^3$) in commercial areas.

All the values of $PM_{10}$ were above the prescribed National Ambient Air Quality Standard (NAAQS) of 100 $\mu g/m^3$ 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 92.1 to 101.6 $\mu g/m^3$ with an average of 97.1 $\mu g/m^3$. In commercial areas (Charbagh, Alambagh, Aminabad and Chowk) the average concentrations of $PM_{2.5}$ were in the range of 112.7 to 130.6 $\mu g/m^3$ with an average of 120.9 $\mu g/m^3$ respectively. In industrial area (Amausi), the average concentrations of $PM_{2.5}$ was 114.3 $\mu g/m^3$.

The maximum 24 hours mean concentration of $PM_{2.5}$ was observed in Indira Nagar (101.6 $\mu g/m^3$) in residential area and Alambagh (130.6 $\mu g/m^3$) in commercial area.

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

### 1.3.3. Superfine Particles ($PM_{0.56}$, $PM_{0.32}$, $PM_{0.18}$)

The monitoring was conducted during the month of October 2015 at three locations Parivartan Chowk (commercial area), Gomti Nagar (residential Area) and CSIR-IITR Gheru campus (rural area).

The 24 hours mean concentration of $PM_{0.56}$, $PM_{0.32}$, $PM_{0.18}$ were found to be 17.11, 11.78 and 12.76 $\mu g/m^3$ at commercial area, 17.98, 12.27 and 9.91 $\mu g/m^3$ for residential area and 5.67, 6.84 and 3.56 $\mu g/m^3$ for rural area respectively. There are no Indian standards recommended by the MOEF, Govt. India these particles.

### 13.4. Ultrafine Particles ( $PM_{0.10}$ and , $PM_{0.056}$)

The 24 hrs mean concentration of $PM_{0.10}$ and, $PM_{0.056}$ were found to be 9.54, and 9.87 for commercial area, 18.87 and 9.76 for residential area and 4.32 and 2.85 $\mu g/m^3$ for rural area respectively. There no Indian standards recommended by the MOEF, Govt. India for these particles.

### 1.3.5 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 17.0 to 21.3 $\mu g/m^3$ with an average of 18.2 $\mu g/m^3$. In commercial areas (Charbagh, Alambagh, Aminabad and Chowk) the average concentrations of $SO_2$ were in the range of 18.3 to 22.4 $\mu g/m^3$ with an average of 21.8 $\mu g/m^3$. In industrial area (Amausi) the mean level of $SO_2$ was 20.6 $\mu g/m^3$. All the values of $SO_2$ were well below the prescribed NAAQS of 80 $\mu g/m^3$ for all the locations.

### 1.3.6 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 to be in the range of 55.1 to 67.3 $\mu g/m^3$ with an average of 60.0 $\mu g/m^3$. In commercial areas (Charbagh, Alambagh, Aminabad and Chowk) the average concentrations of $NO_X$ were found to be in the range of 60.8 to 79.7 $\mu g/m^3$ with an average of 72.4 $\mu g/m^3$. In industrial areas Amausi) the average concentration was 75.5 $\mu g/m^3$. All the values of $NO_x$ were within the prescribed NAAQS of 80 $\mu g/m^3$ for all the monitoring locations.

**Table 8: Concentration (µg/m$^3$) of $PM_{10}$, $PM_{2.5}$, $SO_2$ and NOx during Post monsoon 2015**

| Location | $PM_{10}$ (RSPM) | | | $PM_{2.5}$ | | | $SO_2$ | | | NOx | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Residential** | Min | Max | Avg | Min | Max | Avg | Min | Max | Avg | Min | Max | Avg |
| Aliganj | 146.7 | 224.1 | 182.9 | 83.5 | 113.0 | 95.8 | 11.6 | 20.5 | 17.0 | 44.7 | 67.3 | 58.8 |
| Vikas Nagar | 155.0 | 272.6 | 199.5 | 75.3 | 128.8 | 99.0 | 13.2 | 19.6 | 17.3 | 54.2 | 73.2 | 59.1 |
| Indira Nagar | 155.8 | 310.0 | 218.2 | 84.4 | 127.8 | 101.6 | 15.6 | 26.8 | 21.3 | 63.5 | 73.9 | 67.3 |
| Gomti Nagar | 132.2 | 235.2 | 180.4 | 69.4 | 134.4 | 92.1 | 12.5 | 22.6 | 17.5 | 42.1 | 62.5 | 55.1 |
| **Commercial** | | | | | | | | | | | | |
| Charbagh | 169.7 | 285.9 | 235.0 | 103.0 | 144.4 | 123.4 | 15.4 | 27.6 | 23.3 | 67.2 | 89.4 | 79.7 |
| Alambagh | 143.4 | 349.8 | 264.9 | 75.5 | 158.9 | 130.6 | 14.3 | 28.5 | 22.4 | 66.7 | 85.9 | 76.9 |
| Aminabad | 163.1 | 274.4 | 215.5 | 63.3 | 150.6 | 112.7 | 14.8 | 22.6 | 18.3 | 47.2 | 68.8 | 60.8 |
| Chowk | 158.7 | 341.4 | 260.1 | 77.2 | 159.7 | 116.9 | 15.8 | 28.1 | 23.4 | 52.1 | 86.0 | 72.3 |
| **Industrial** | | | | | | | | | | | | |
| Amausi | 142.2 | 313.9 | 214.2 | 96.3 | 138.9 | 114.3 | 12.8 | 25.5 | 20.6 | 65.8 | 82.6 | 75.5 |
| NAAQS | 100 | | | 60 | | | 80 | | | 80 | | |
| WHO Guidelines | 50 | | | 25 | | | 20* | | | 40* | | |

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

**Table 9: Concentration (µg/m$^3$) of Superfine and Ultrafine Particles during Post monsoon 2015**

| | Commercial | | | Residential | | | Village/Rural | | |
|---|---|---|---|---|---|---|---|---|---|
| | Min | Max | Avg. | Min | Max | Avg. | Min | Max | Avg. |
| Superfine | | | | | | | | | |
| $PM_{0.56}$ | 14.34 | 21 | 17.11 | 14.67 | 20.21 | 17.98 | 4.42 | 6.11 | 5.67 |
| $PM_{0.32}$ | 9.11 | 19.1 | 11.78 | 9.96 | 15.34 | 12.27 | 6.12 | 7.34 | 6.84 |
| $PM_{0.18}$ | 9.01 | 16.1 | 12.76 | 8.98 | 11.44 | 9.91 | 2.81 | 4.56 | 3.56 |
| Ultrafine | | | | | | | | | |
| $PM_{0.1}$ | 7.21 | 10.69 | 9.54 | 6.12 | 10.77 | 8.87 | 2.98 | 5.87 | 4.32 |
| $PM_{0.056}$ | 5.66 | 10.78 | 9.87 | 7.01 | 10.32 | 9.76 | 1.71 | 3.21 | 2.85 |
| Total | | | **61.06** | | | **58.79** | | | **23.24** |

N=5

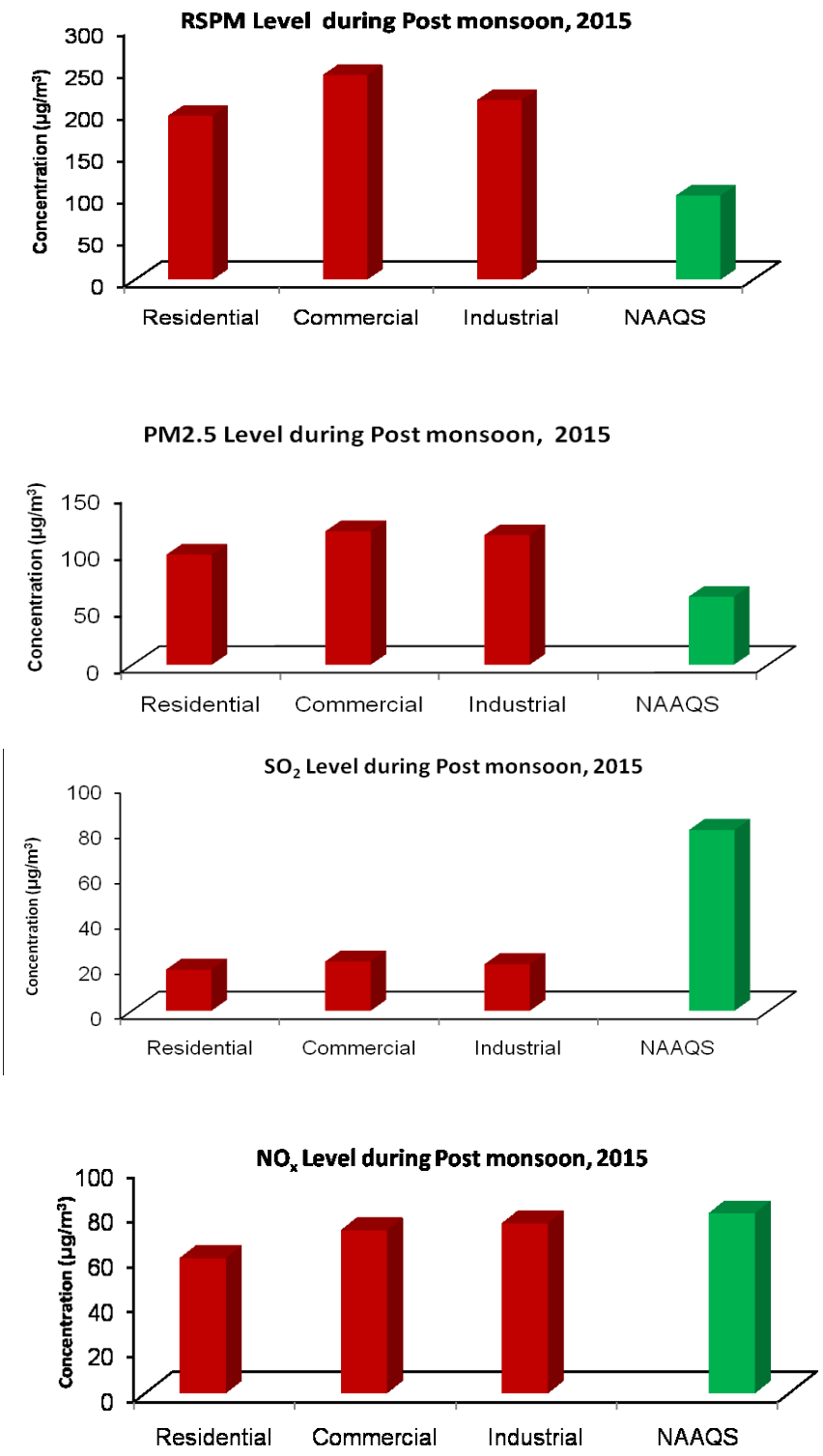



**Fig 1:** Concentration (µg/m$^3$) of $PM_{10}$, $PM_{2.5}$, $SO_2$ and $NO_x$ in different areas of Lucknow city during Post monsoon season (2015) and compared with prescribed National Ambient Air Quality Standard (NAAQS)

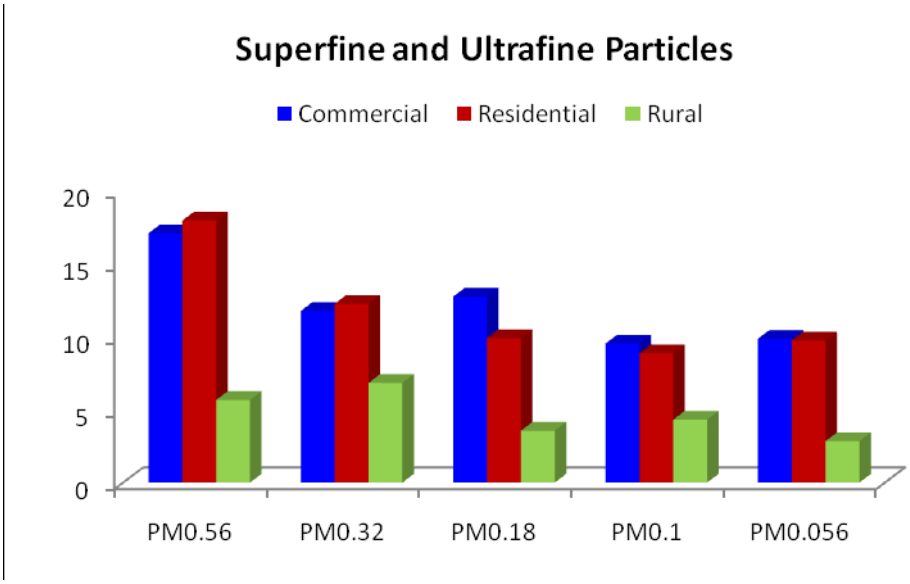



**Fig 2:** Concentration (µg/m$^3$) of Superfine and Ultrafine Particles in different areas of Lucknow city

### 1.3.7 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 hours mean concentration of metals were found to be Pb = 315.64 (65.20-410.9) and Ni = 18.86 (12.11 – 25.49) $ng/m^3$.

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

| Sl. No. | Location | Lead (Pb) | Nickel (Ni) |
|---|---|---|---|
| 1 | Aliganj | 55.91 | 14.53 |
| 2 | Vikas Nagar | 93.80 | 24.53 |
| 3 | Indira Nagar | 80.72 | 18.78 |
| 4 | Gomti Nagar | 65.20 | 12.11 |
| 5 | Charbagh | 410.98 | 25.49 |
| 6 | Alambagh | 192.66 | 19.94 |
| 7 | Aminabad | 87.84 | 15.10 |
| 8 | Chowk | 78.07 | 21.19 |
| 9 | Amousi | 156.5 | 18.25 |
| **Mean** | | **135.64** | **18.86** |
| **NAAQS** | | **1000** | **20*** |

N= 1, *=Annual Average

### 1.3.8 Noise

The monitoring data recorded during the post monsoon period (October, 2015) is presented in Table 11.

In residential areas, the day and night time noise levels were recorded between 64.6 to 66.8 and 53.1 to 56.4 dB(A) respectively. All the values were higher than the prescribed limit 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 71.7 to 75.5 and 53.1 to 70.2 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 as 68.7 and 63.1 dB (A) respectively. Noise levels at all industrial locations in the day and night time was found below the prescribed limits of 75.0 and 70.0 dB(A) respectively.

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

| Sl. No. | Area | Location | Noise level dB(A) | |
|---|---|---|---|---|
| | | | Day | Night |
| 1 | **Residential** | Aliganj | 64.7 | 56.4 |
| | | Vikas Nagar | 65.8 | 55.3 |
| | | Indira Nagar | 66.8 | 56.7 |
| | | Gomti Nagar | 64.6 | 53.1 |
| | | **Standard** | **55.0** | **45.0** |
| 2 | **Commercial** | Charbagh | 73.8 | 70.2 |
| | | Alambagh | 71.7 | 64.7 |
| | | Aminabad | 73.5 | 53.1 |
| | | Chowk | 75.5 | 62.5 |
| | | **Standard** | **65.0** | **55.0** |
| 3 | **Industrial** | Amausi | 68.7 | 63.1 |
| | | **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 have been compared to find out the prevailing trend of air pollution in Lucknow city (Fig. 3-5). 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 except Indira Nagar whereas higher values were also observed in all the commercial areas and one industrial area also showed higher value when compared to the data of the previous year. All the values are higher than the NAAQS (Fig. 3).

### 1.4.2 Sulphur dioxide ($SO_2$)

The level of $SO_2$ during post monsoon since 2012 is presented in Fig. 4 for all the locations.

In residential areas, little higher concentration of $SO_2$ was found compared to that of the previous year at all the locations. Among the commercial areas, $SO_2$ values showed slightly increasing trend over the last year. Amausi, industrial area also showed increasing trend over the last year. All the values of the present study were found to be lower than the NAAQS (Fig. 4).

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

The level of NOx during post monsoon since 2012 is presented in Fig. 5 for all the locations. Among the residential areas all the locations showed increasing trend at all the locations, where as in commercial areas, all the locations also showed increasing trend except Charbagh which showed slightly lower value and the only industrial area Amausi 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 (Fig. 5).

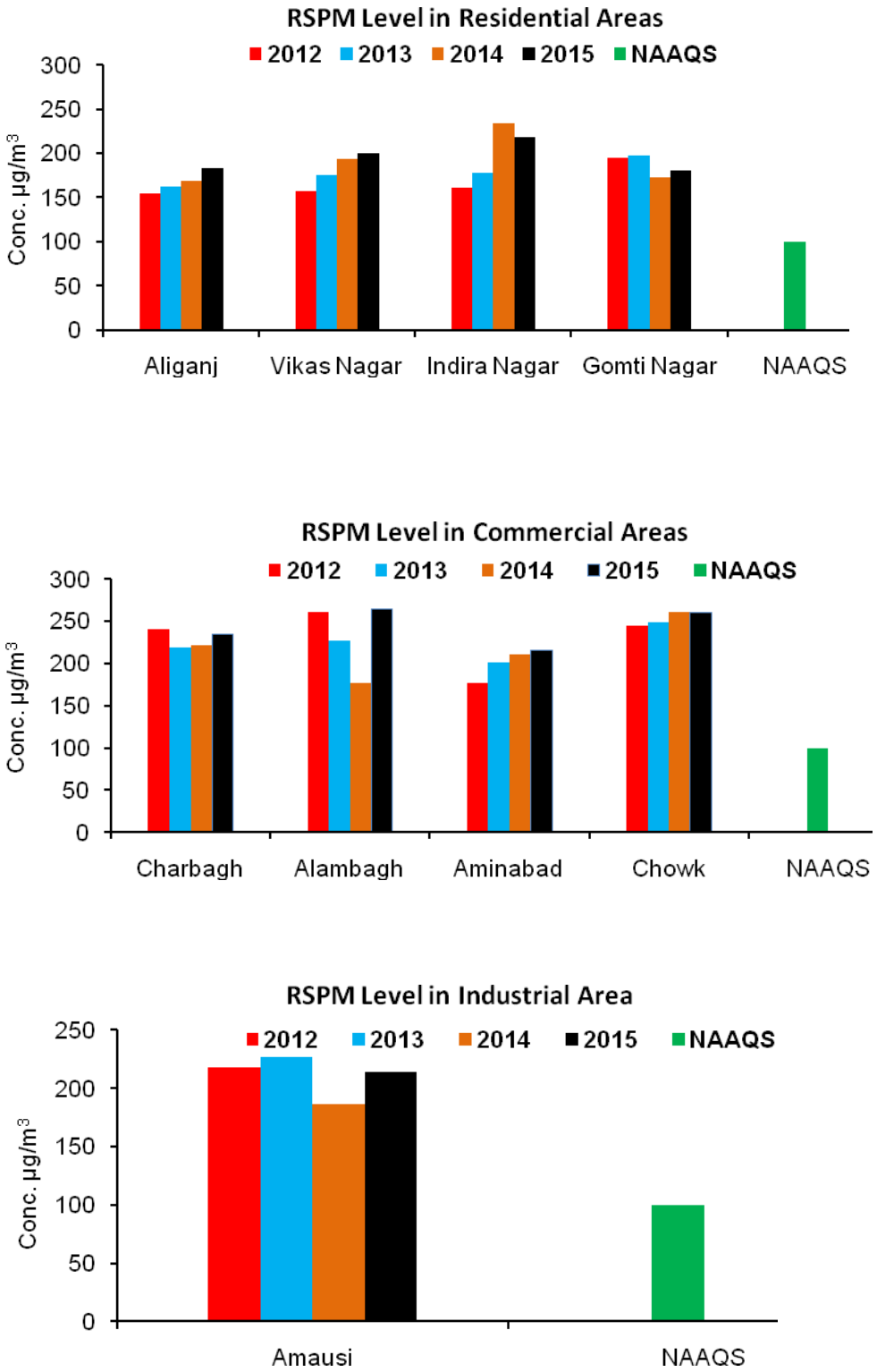



**Fig 3:** Concentration (µg/m$^3$) of $PM_{10}$ **(**RSPM**)** in Residential, Commercial and Industrial areas of Lucknow city during 2012 to 2015 and compared with prescribed National Ambient Air Quality Standard (NAAQS)

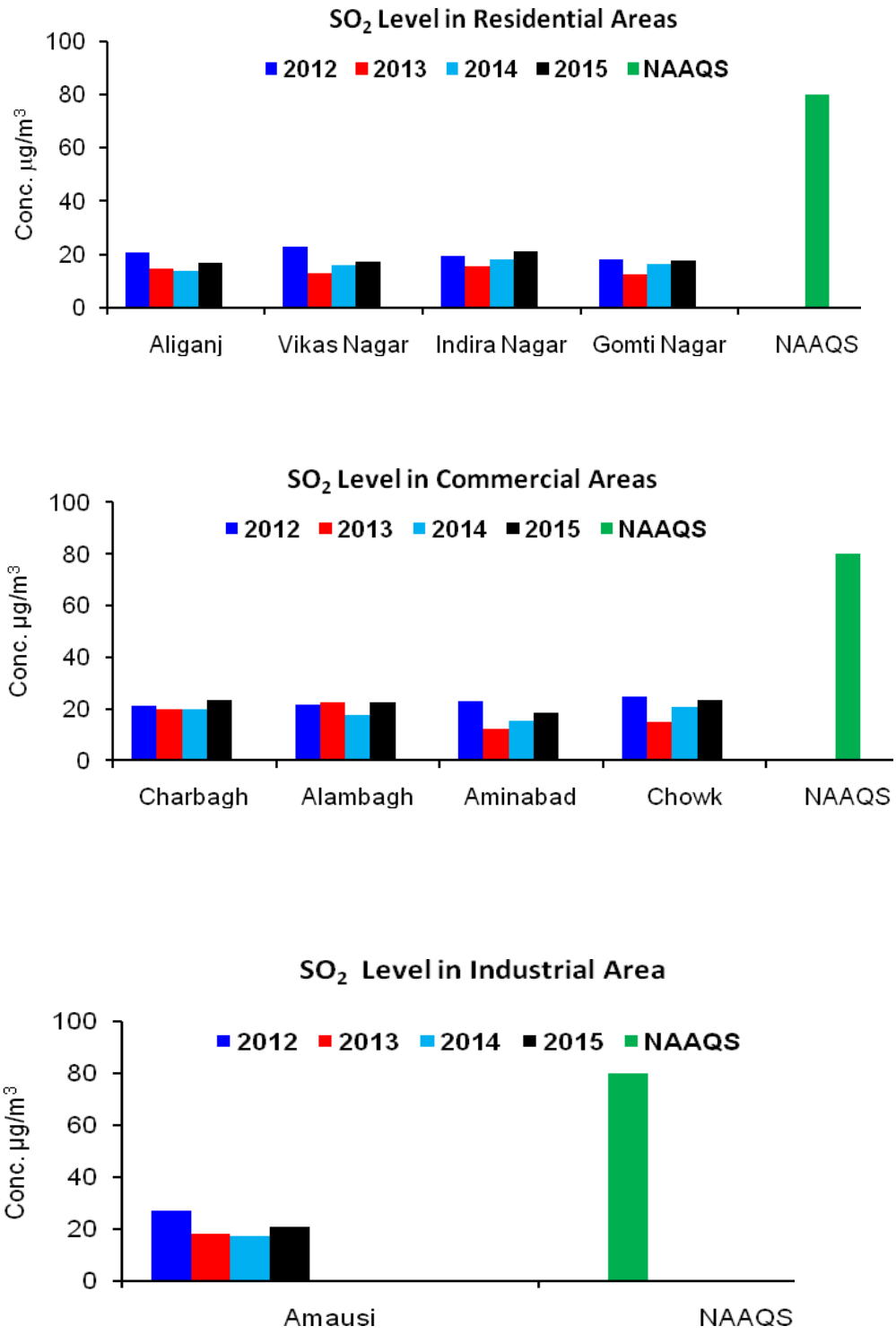



**Fig 4:** Concentration (µg/m$^3$) of $SO_2$ in Residential, Commercial and Industrial areas of Lucknow city during 2012 to 2015 and compared with prescribed National Ambient Air Quality Standard (NAAQS)

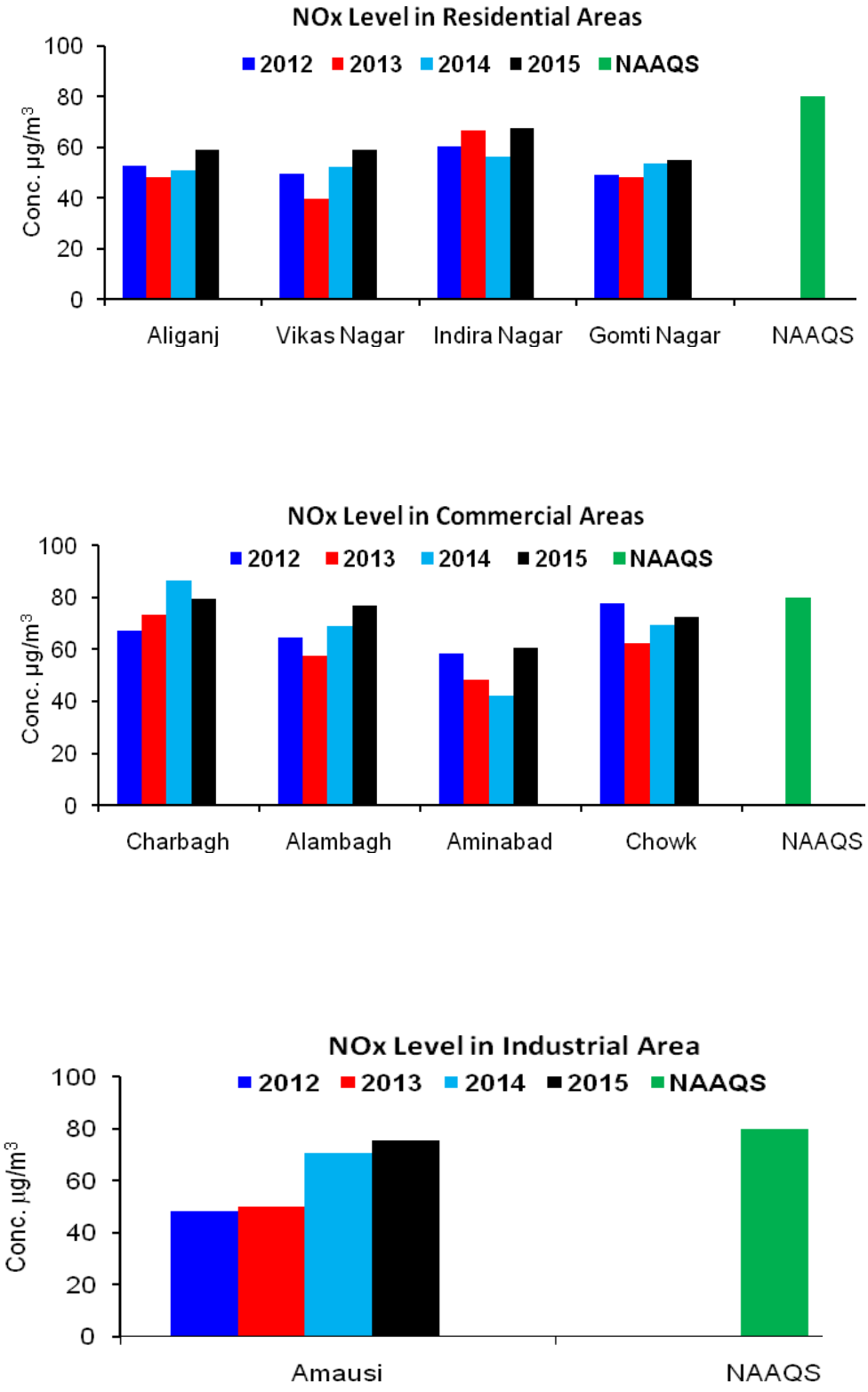



**Fig 5:** Concentration (µg/m$^3$) of $NO_x$ in Residential, Commercial and Industrial areas of Lucknow city during 2012 to 2015 and compared with prescribed National Ambient Air Quality Standard (NAAQS)

### 1.4.4 Noise Level

Current year's noise data has been compared with the corresponding data of the previous three years (2012 to 2015) and are presented in Fig. 6 and 7. The comparative noise levels in residential, commercial and industrial areas are described below:

#### 1.4.4.1 Day time Noise Level

In residential areas, all the locations showed slightly lower trend over that of the previous year. In commercial cum traffic areas, noise level was found to be on the higher side at Aminabad and Chowk compared to that of previous year, except at Alambagh. In industrial area, Amausi the noise level was slightly lower than that of the previous year. The comparative data are presented in (Fig.6).

#### 1.4.4.2 Night time Noise Level

Residential areas showed slightly lower level than that of the last year except Vikas Nagar. In commercial areas, little variation was recorded and the only industrial area showed slightly lower value than that of the previous year. The comparative data are presented in (Fig. 7).

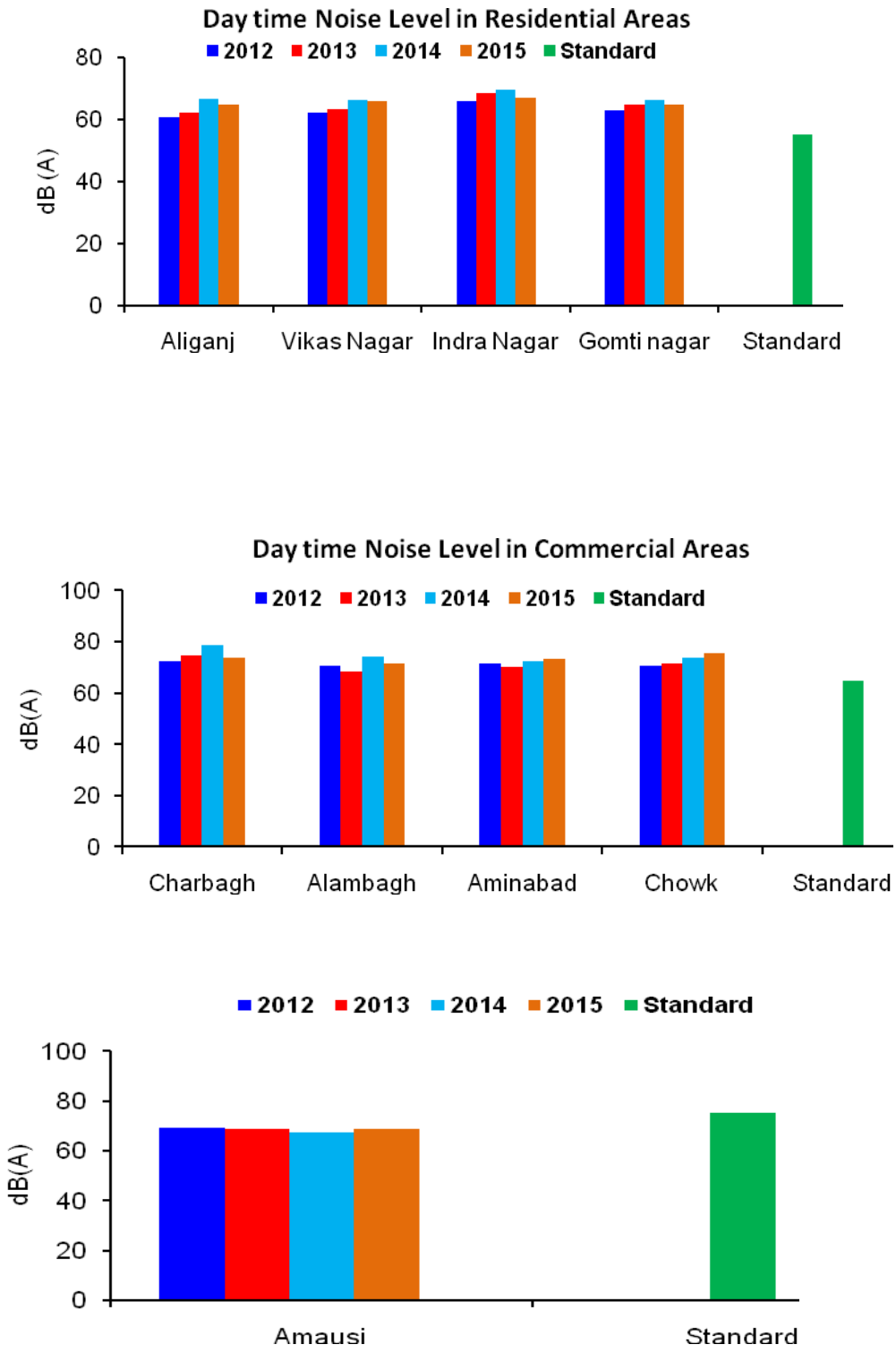
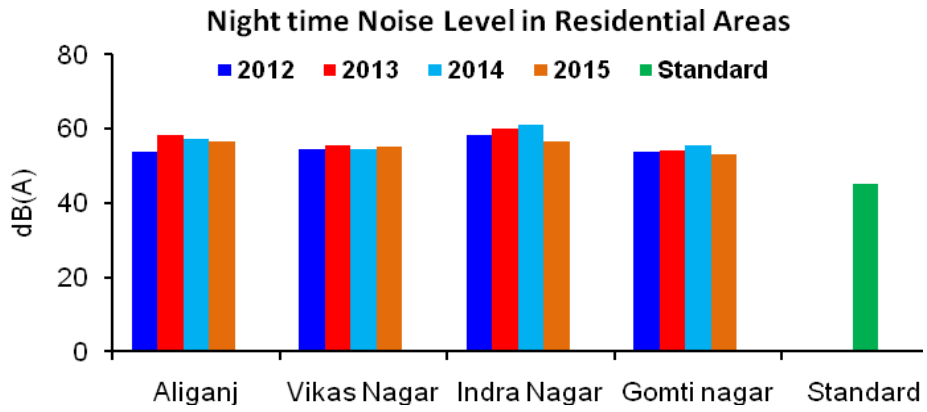
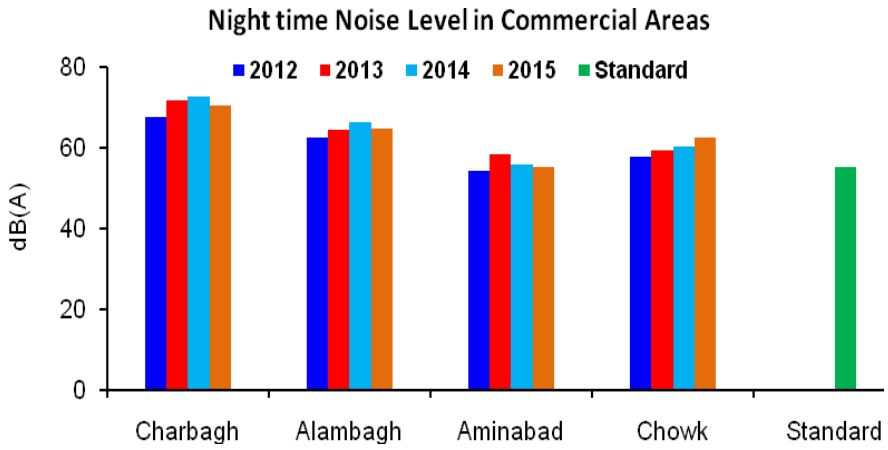



**Fig 6:** Comparison of day time Noise Level dB(A) in different areas of Lucknow city (2012-2015)



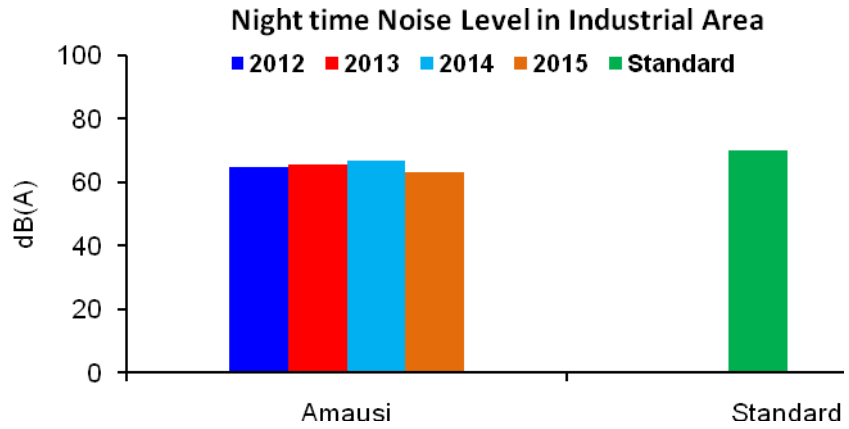




**Fig 7:** Comparison of night time Noise Level dB(A) in different areas of Lucknow city (2012-2015)

## 1.5 HEALTH EFFECTS

The adverse effects mainly depends on the nature and concentration of air pollutants and the status of the receptor. Accumulation of pollutants in the human body through inhalation of air is an important route. Results of the present study revealed that higher level of particulate matter ($PM_{10}$ and $PM_{2.5}$) at all the monitoring locations may be responsible for several cardiovascular and respiratory diseases such as asthma, bronchitis, reproductive impairment, increased risk of preterm birth and even mortality and morbidity rate.

It will be appropriate to mention here that the monitoring values of superfine and ultrafine particles concentration are much higher than the control area and may have serious health effect.

Human exposure to particulate air pollution has been identified as a risk factor for human mortality and morbidity and many countries have revised the limits for $PM_{10}$ and $PM_{2.5}$. Nevertheless, PM threshold levels to which exposure does not lead to adverse effects on human health have not yet been clearly identified and there is substantial inter-individual variability in exposure and in the response and it is difficult to establish a standard or guideline value that will lead to complete protection of every individual against all possible adverse health effects of particulate matter.

The effect of PM depends on the mass and number concentration, shape and size and the composition and concentration of other inorganic and organic pollutants associated with it. We also estimated the trace metals associated with $PM_{10}$. The high level of Pb can induce severe neurological and hematological effects on the exposed population especially children, whereas Ni is known for inducing carcinogenic effects in humans through inhalation.

In the present study, the concentration of $SO_2$ and NOx were found to be below permissible limit (80 $\mu g/m^3$) 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 post monsoon (September - October), 2015 we have monitored air pollutants such as $PM_{10}$, $PM_{2.5}$, Superfine and Ultrafine particles, $SO_2$, NOx and trace metals for 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 levels of Fine particles ($PM_{2.5}$) at all the monitoring locations of residential, commercial and industrial areas were higher than the NAAQS.

- The total mass concentration of superfine and ultrafine particles were found to be higher in the commercial as well as in the in residential areas and almost double the control/rural values which indicate the release of the smaller particles in urban area due vehicular pollution or anthropogenic activities. It is remarkable that total concentration of these particles were found to be near/ equal to permissible limit of $PM_{2.5}$ (60 $\mu g/m^3$). At present there is no Indian standard of these particles.

- The concentration of gaseous pollutants, $SO_2$ and $NO_x$ were below the prescribed NAAQS (80 $\mu g/m^3$) at all the locations but showed slightly mixed trend.

- 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 $PM_{2.5}$ and associated metals are one of the major causes for deterioration of ambient air quality.

Unlimited growth of number of vehicles, their technological development and release of invisible tailpipe pollutant emissions are serious debatable issues even for the policy makers. Use of different types of fuels namely petrol, diesel, LPG and CNG make the environment more complex regarding the air quality and their synergistic effects on the human health.

The higher level of air pollution in the city was also attributed to the construction of a number of large parks and memorials, construction of new roads pavements and their repair and maintenance, construction of multistoried buildings and movements of heavy vehicles carrying construction materials, garbage dumps in the city and movement of garbage trucks etc,.

Lucknow is not an industrial town but scattered industries in the industrial areas of the city and small workshops are also adding to the air pollution to some extent. At present, metro rail section from Airport to Charbagh railway station on Kanpur road is under progress. This activity may affect air quality of the area due to construction activities as well as traffic congestion. On this route for the above mentioned activities, many trees on the side of roads have been cut down by authorities, reducing the sink available to absorb the air pollution in the city. In addition to this, abnormal meteorological conditions of the city also adversely influence the ambient air quality of the city.

Overall, continuous accumulation of different types of pollutants and their exposure to human beings needs immediate attention of the policy maker, researchers and regulatory agencies

The present study suggests that it is necessary to monitor the air quality as well as the health effects at regular intervals at strategic locations. Our pre and post monsoon monitoring surveys might be of help to focus on the pollution level in Lucknow city and its probable consequences. Our database since 1997 would help the planners in sustainable development of the city.

## 1.7 RECOMMENDATIONS

- Subsidized public mass transport (Metro, Monorail etc.) must be introduced/strengthened to minimize use of personal vehicles.
- Traffic management should be improved.
- Road side encroachment should be removed for the smooth flow of traffic.
- Public awareness programme for reduction of automobile pollution should be conducted.
- Pressure horns to be removed from all vehicles and use of horn should be avoided/minimized.

- Parking charges should be increased to discourage the use of personal vehicles.
- Battery operated vehicles should be encouraged
- Foot path for pedestrians should be restored.

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सीएसआईआर-भारतीय विषविज्ञान अनुसंधान संस्थान
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- Food, Drug & Chemical Toxicology
- Environmental Toxicology
- Regulatory Toxicology
- Nanotherapeutics & Nanomaterial Toxicology
- Systems Toxicology & Health Risk Assessment

## Services Offered

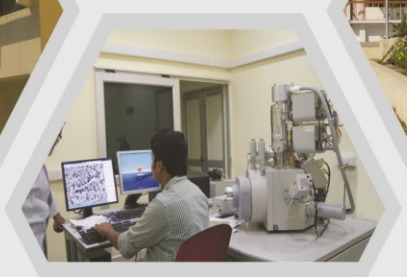
- GLP certified for pre-clinical toxicity studies
- NABL accredited
- Safety / toxicity evaluation of NCEs
- Water quality assessment and monitoring
- Analytical services
- Environmental monitoring and impact assessment
- Epidemiological studies
- Information on chemicals / products

## Recognitions

- Scientific & Industrial Research Organizations (SIROs)
- UP Pollution Control Board (Water & Air)
- Indian Factories Act (Drinking Water)
- Bureau of Indian Standards (Synthetic Detergents)
- Food Safety & Standards Authority of India (FSSAI)

## Technologies Developed / Available

- Water Analysis Kit
- Mobile Laboratory Van for on spot water quality analysis
- Argemone Detection Kit for rapid screening of Argemone in mustard oil
- CD-Strip for detection of butter yellow, an adulterant in edible oils
- Arsenic Detection Kit

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