ASSESSMENT OF AMBIENT AIR QUALITY OF LUCKNOW CITY

(Pre-Monsoon-2016)

Findings of a Random Survey

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Salient Features of the Study

❖ **Geographical Position**	**:**	26^o 52' N Latitude 80^o 56' E Longitude 128 m above Sea Level
❖ **Area**	**:**	310 sq. km.
❖ **Population**	**:**	28,15033 as per 2011 Census
❖ **Projected Population**	**:**	45 lakhs as per *Master Plan 2021*
❖ **Climate**	**:**	Subtropical climate, cool dry winter (Dec.- Feb.) & summer (Mar - Jun.). Temperature about 45^0C in summer to 3^0C in winter. Average annual rainfall about 100 cm.
❖ **Total Vehicular Population in Lucknow city as on 31/03/2016**	**:**	18,64,556
❖ **Growth of Vehicle over 2014-2015**	**:**	9.06%
❖ **Total No. of Filling Stations (Petrol/Diesel/CNG)**	**:**	125
❖ **Consumption of Petrol**	**:**	1,73,617 KL
❖ **Consumption of Diesel**	**:**	1,82,481 KL
❖ **Consumption of CNG**	**:**	3,02,46,000 Kg
❖ **Major Sources of Pollution**	**:**	Automobiles, D. G. sets, Civil Constructions
❖ **Parameters Monitored**	**:**	PM_{10}, $PM_{2.5}$, SO_2, NO_x, trace metals and noise level.
❖ **Study Conducted by**	**:**	Environmental Monitoring Division CSIR- IITR, Lucknow

ASSESSMENT OF AMBIENT AIR QUALITY OF LUCKNOW CITY DURING PRE-MONSOON, 2016

Environmental Monitoring Division
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1.0 SUMMARY

The study was carried out during the months of April-May, 2016 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 (NO_x); trace metals such as Lead (Pb) and Nickel (Ni); 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 124.6 to 367.2µg/m^3 with an average of 223.3 µg/m^3. The 24 hours concentration of $PM_{2.5}$ was found to be in the range of 61.2 to 175.4 µg/m^3 with an average of 107.4 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). 24 hours concentration of SO_2 and NO_x were found to be in the range of 7.8 to 20.1 and 25.2 to 63.8 µg/m^3 with an average concentration of 12.4 and 42.9 µg/m^3 respectively and all the values were below the permissible limits (80 µg/m^3). The mean level of trace metals were Ni = 39.51 and Pb = 124.52 ng/m^3. Noise levels during day and night time were found to be in the range of 70.1 to 76.6 dB(A) and 55.8 to 70.9 dB(A) respectively which was above the respective permissible limits except in industrial area.

1.1 INTRODUCTION

Air quality has become an important subject for discussion in recent years. There was a purity and cleanliness in the air environment when we talk about 80's. The periphery of Lucknow city was small and the surrounding areas were mainly occupied either by vegetation cover or small water resources. Such conditions were favorable for better air quality of the region. Many water resources were present in the nearby city areas resulting in good water table levels with greenery in the form of agricultural fields, vegetable fields and mango orchards etc. These fields used to act as a kind of natural green belt around the city. The rampant development which began in the early 90's has engulfed these green areas around the city which are now converted to densely populated residential and commercial areas. As a result, the air pollution sink has depleted and these areas have added to air pollution resulting in poor air quality in the city.

Now there is a greater need to create awareness to mitigate disastrous consequences of environmental degradation. Today cities are turning into

more of the urban areas with rapid commercial and industrial development. The atmosphere is in an extremely vulnerable condition because of the ever increasing number of vehicles on roads of Lucknow. Vehicular pollution (mobile sources) accounts as a major source to the city's air pollution and remaining pollution is contributed by other polluting sources (point sources) at present. Particulate matter has been recorded as the major pollutant of Lucknow city as per our survey. The city is located in Indo-Gangetic plain. This zone is rich with highly fertile fine grained soil that becomes air borne easily during construction, agricultural and transport activities. The pollution from activities of dense population, industrial activities, commercial activities and vehicles add to the particulate level. This zone experiences severe cold in winter spanning from about 3 to 4 months. Typical meteorological conditions in winter with low wind speed and low mixing height restrict diffusion, dilution and transport of air pollutant resulting in high levels. The rains that help wash down of air pollutants are reducing year by year. The dry weather and hot summer persists for most of the year with high wind speed keeping airborne particles for longer duration.

The WHO 2016 report is also in the same lines as our findings of the air pollution survey's of Lucknow City during the last 15 years. Even some of the smaller cities have gained top positions over large cities in the WHO list. This trend indicates that the activities in smaller cities are of a similar nature and also increasing, particularly the increase in vehicular pollution is irrespective of the size of a city. Therefore, in general the particulate level in the urban areas is increasing rapidly. Out of top 20 global cities, half the number i.e. 10 spots are occupied by north Indian cities and 5 cities of UP.

Exposure to high air pollution levels resulted in adverse health effects i.e. the initial symptoms show decrease in lung function, asthma, coughing and difficulty in breathing, etc. Urban population is reported to be suffering from different air pollution induced respiratory and pulmonary diseases with higher morbidity and mortality. The health effects of air pollution depend on the nature and level of air pollutants, which in turn depend on the pollution sources. Like other urban areas Lucknow has all the major sources of air pollution including domestic, commercial, industrial and vehicular emissions. Usage of gensets for electric supply during power failures is also contributing to the air pollution. Combustion of fuels and solid waste burning produces Particulate matter ($PM_{2.5}$ & PM_{10}), SO_2, NO_x, CO, CO_2, trace metals, benzene, Benzo-a-pyrene and a number of volatile organic compounds in the city environment. Besides adverse health effects, these pollutants are also responsible for the global warming.

People are getting more and more aware about the air pollution problem. Authorities are also sensitizing towards the gravity of the problem. Our reports of pre and post monsoon surveys over the years have played a vital role in bringing awareness. Steps like introduction of CNG as vehicular fuel, widening of roads and construction of flyovers has been done during last few years. But the efforts made so far have been proved to be inadequate and the air pollution levels in the city are still on higher side. Reasons for this situation could be increase in number of vehicles, volume of fuel consumption, construction and other activities and traffic jams etc. Metro construction is also under

progress in the city, which may be helpful in reducing the pollution in future. By the time metro starts functioning things will change. However, it is expected from the people to think about sustainable development as well as the rational use of natural resources for betterment of their own health and environment.

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). The city witnessed development of new areas like Mahanagar, Indira Nagar, Aliganj, Gomti Nagar towards the end of the 20^{th} century. During the last 20 years, rapid development has taken place in the city and practically most of the open space available has been occupied for the construction of residential, commercial and office buildings. Population density of city is increasing. Pressure on management of services, facilities and amenities is also increasing.

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 **:** 18,64,556 as on 31.03.2016 which is 9.06% 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 31.03.2016 are given in Table 2. In Lucknow city there are 125 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 1,73,617 and 1,82,481 KL as on 31-03-2016. It is observed that petroleum sale has increased by 16.3 % whereas sale of diesel has increased by 15.1 %. (Table 4). In Lucknow there are nine CNG filling stations and consumption of CNG in the last year was approximately 3,02,46,000 kg (2015-16) which was 9.03% higher than the previous year (2014-15) (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), 2016 with respect to PM_{10}, $PM_{2.5}$, 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, NO_x, 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 2014-15 and 2015-16

Sl. No.	Type of Vehicle	Number of Registered Vehicles on 31st March		% Change
		2014-15	2015-16	
1	Multi Articulated	3514	3891	10.73
2	Light, Medium and Heavy weight Vehicles (Four wheeler)	20930	23188	10.79
3	Light commercial vehicles (Three wheeler)	3413	3537	3.63
4	Buses	3306	3466	4.84
5	Taxi	9153	11957	30.63
6	Light Motor Vehicles (Passenger)	7562	9019	19.27
7	Two wheelers	1361787	1480458	8.71
8	Car	244121	267012	9.38
9	Jeep	26019	30399	16.83
10	Tractor	23679	25094	5.97
11	Trailors	1580	1648	4.30
12	Others	4598	4887	6.28
Total		**1709662**	**1864556**	**9.06**

Source: RTO, Lucknow

Table 2: Details of Lucknow City Bus Service, 2016

Sl. No.	Route No.	To and Fro	No. of Buse	Frequency
1	11	BBD – Chinhat - Gomti Nagar - Alambagh	18	10 minutes 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 - Tewari ganj -BBD - Chinhat - HAL Nishatganj - Sikindrabad - KKC College - Charbagh	16	10 minutes interval
3	13	Charbagh - Mawwaiya - Alambagh thana - Terhi Pulia – Alambagh bus stand - Awadh Hospital – Krishna Nagar thana - Natherganj - Scooter India - Koti Bagia.	06	10 minutes interval
4	23	Integral University - Gudamba - Vikasnagar – Nishatganj - Sikandrabad - Hussaingaj - Alambagh - Rajnikhand	17	10 minutes interval
		Gudamba - Badshanagar - Avadh Hospital		
5	24	Engineering College - Khurram Nagar sector 19 - Munshipulia - Indira Nagar - Nishatganj - Charbagh - Alambagh - Paasi- Kila.	10	20 minutes interval
6	24 L.U.	Sahid path - BBA University - Paasi Kila - Alambagh - Charbagh - Burlington - Kaiserbagh Chowraha - Parivartan chowk – Kapoorthala – Purania Chowraha - Engineering College.	2	15 minutes interval
7	31	IM sector Q - Beligaradh - PNT-Purania - Kapoorthala - ChanniLal - Mahanagar - Goal market - Badhshanagar - Nishatganj - Hussainganj - Charbagh - Alambagh Chowraha.	2	60 minutes interval
8	31 A	Charbagh - Hussainganj - Sikandrabagh - Gokhale Marg - Nishatganj - Badshanagar - Goal market - Channilal - Kapoorthala -Purania - Engineering College - Sewa Hospital - Bakshi Ka Talab	1	120 minutes
9	33	Engineering College - Charbagh - Alambagh - Scooter India	14	15 minutes interval
10	33 C	Bhitoli - CDRI Chowraha - Jankipuram - Purania - Mahanagar - Badshanagar - Nishatganj - Hussainganj - Charbagh - Alambagh Cowraha.	2	60 minutes interval
11	33 S	Bhitoli Chowraha - Engineering College – Kapoorthala - Badshanagar – Nishatganj – Hussainganj – Charbagh – Alambagh - Bhudeswar Chowraha - Dr. Sukuntala Mishra University.	1	180 minutes interval
12	33 M	Alambagh Chowraha - Charbagh - Hussainganj - Nishatganj - Kapoorthala - Purania - Engineering College - Modium.	1	120 interval
13	33 PGI	SGPGI - Telebagh - Alambagh - Charganj - Hussainganj - GPO - Mahanagar - Engineering College.	1	180 minutes
14	33 LU	Parivartan Chowk - IT Chowraha - Vivekananda Hospital - Kapoorthala - Engineering College - New Campus Lucknow University	2	45 minutes
15	45	Virajkhand - Gomti Nagar - Charbagh - Alambagh - Paasi Kila - Aurangabad - Shahid path	14	15 minutes
		Total	107	15 minutes interval

Source: Lucknow City Transport Services Limited.

Table 3: Fuel Outlets in Lucknow City

Sl. No.	Agency	Number of outlets
		31st March 2016
1	Indian Oil Corporation (IOC)	51
2	Bharat Petroleum Corporation Ltd. (BPCL)	38
3	Hindustan Petroleum Corporation Ltd. (HPCL)	27
4	Compressed Natural Gas Stations (CNG)	9
	Total	**125**

Source: Indian Oil Corporation (IOC), Lucknow

Table 4: Consumption of Fuel in Lucknow

Sl. No.	Agency	Petrol in KL			High Speed Diesel in KL			*CNG in Kg		
		Apr. 14 to Mar. 15	Apr. 15 to Mar. 16	% Change	Apr. 14 to Mar. 15	Apr. 15 to Mar. 16	% Change	Apr. 14 to Mar. 15	Apr. 15 to Mar. 16	% Change
1	IOC	82951	90507	9.11	86092	86101	0.01			
2	BPCL	37673	50570	34.23	34179	54990	60.89	---		
3	HPCL	28657	32540	13.5	38263	41390	8.17	---		
4	Green Gas	--			--		--	27740909	30246000	9.03
Total		**149281**	**173617**	**16.3**	**158534**	**182481**	**15.1**	**27740909**	**30246000**	**9.03**

*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

Sl. No.	Vehicles	Number		% of Change
		2014-15	2015-16*	
1	Auto Rickshaws	4343	4343	0
2	Tempo Taxi	2575	2575	0
3	Buses (UPSRTC)	260	260	0
4	Buses (Private)	34	34	0
5	School Buses	1033	1099	6.39
6	School Van	1154	1404	21.66
7	Private Vehicles	205	205	0
8	Private Cars	8940	9783	9.43
	Total	**18544**	**19703**	**6.25**

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

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	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.

1.2.1 Micrometeorology

A meteorological station (Model Envirotech WM 271) is installed at a height of approximate 90 ft on the roof top of CSIR-IITR building. Hourly, meteorological data viz wind speed (WS), Wind Direction (WD), Relative Humidity (RH) and Temperature were recorded during the month of April and May 2016 (upto 25th May 2016) and are presented below.

Temperature: The hourly mean temperature range between 24.8 to 39.6 ^{o}C with an average of 31.5 ^{o}C during April 2016 and during May 2016 temperature ranged between 24.4 to 39.8 ^{o}C with an average of 31.3 ^{o}C.

Relative Humidity : The hourly mean RH range between 16 to 40 % with an average of 27.1 % during April 2016 and during May 2016 RH ranged between 25.3 to 65.9 % with an average of 44.1 %.

Wind Speed and Wind Direction

During the month of April-May, 2016, the predominant wind direction was North North-West (NNW) for 17.4% of the time. The other dominant direction was North West (NW) and West North West (WNW) for 12.8 and 8.98 % the time respectively. The calm recorded during this period is 19.21 % (Fig 1). The wind speed was recorded in the range of 1.8 - 3.6, 3.7 - 7.2, 7.2 - 14.4 and 14.4 - 28.8 Km/ h for 19.2, 12.5, 23.6, 14.2 %, of the time respectively.

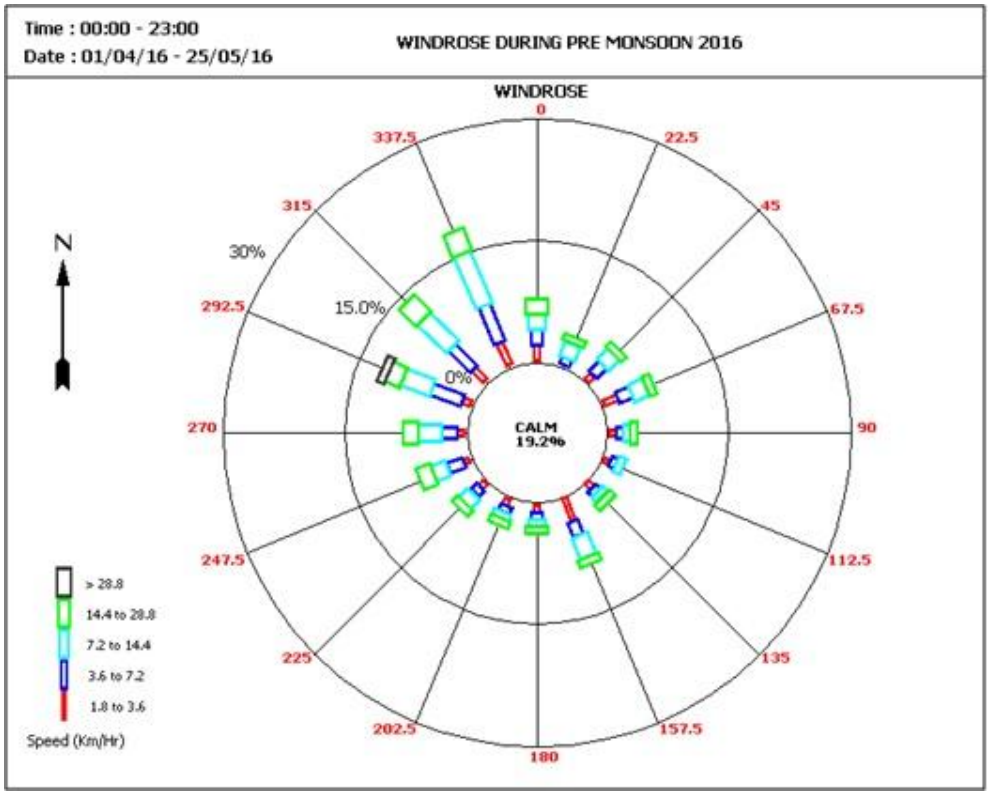

Fig 1: Windrose during the Pre monsoon (April to May 2016)

1.3 RESULTS

The detailed results of air quality monitoring are presented in Table 8 and Fig. 2.

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 186.1 to 221.5 µg/m^3 with an average of 201.4 µg/m^3. In commercial areas (Charbagh, Alambagh, Aminabad and Chowk) the average concentrations of PM_{10} were in the range of 203.3 to 276.7 µg/m^3 with an average of 230.1 µg/m^3 respectively. In industrial area (Amausi), the average concentration of PM_{10} was 238.3 µg/m^3.

The maximum 24 hours mean concentration of PM_{10} was observed in Indira Nagar (221.5 µg/m^3) in residential area and Chowk (276.7 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 88.7 to 115.1 µg/m^3 with an average of 100.8 µg/m^3. In commercial areas (Charbagh, Alambagh, Aminabad and Chowk) the average concentrations of $PM_{2,5}$ were in the range of 102.6 to 119.2 µg/m^3 with an average of 110.2 µg/m^3 respectively. In industrial area (Amausi), the average concentration of $PM_{2.5}$ was 111.3 µg/m^3.

The maximum 24 hours mean concentration of $PM_{2.5}$ was observed in Indira Nagar (115.1 µg/m^3) residential area and Charbagh (119.2 µg/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 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 10.4 to 13.1 µg/m^3 with an average of 12.0 µg/m^3. In commercial areas (Charbagh, Alambagh, Aminabad and Chowk) the average concentrations of SO_2 were in the range of 12.0 to 14.6 µg/m^3 with an average of 13.3 µg/m^3. In industrial area (Amausi), the mean level of SO_2 was 11.9 µg/m^3.

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

1.3.4 Oxides of Nitrogen (NO_x)

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 33.7 to 52.2 µg/m^3 with an average of 39.5 µg/m^3. In commercial areas (Charbagh, Alambagh, Aminabad and Chowk) the average concentrations of NO_x were found in the range of 37.1 to 51.1 µg/m^3 with an average of 44.1 µg/m^3. In industrial areas (Amausi), the average concentration was 45.3 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 2016

Location	PM_{10} (RSPM)			$PM_{2.5}$			SO_2			NO_x		
Residential												
	Min	**Max**	**Avg**	**Min**	**Max**	**Avg**	**Min**	**Max**	**Avg**	**Min**	**Max**	**Avg**
Aliganj	148.5	234.2	193.2	80.7	133.1	99.5	9.6	11.5	12.5	26.6	40.0	34.4
Vikas Nagar	141.8	283.4	186.1	62.7	131.7	88.7	8.5	14.7	12.1	30.3	46.7	37.6
Indira Nagar	147.5	367.2	221.5	72.7	175.4	115.1	9.5	17.0	13.1	40.7	62.9	52.2
Gomti Nagar	158.0	260.2	204.6	78.0	131.7	99.9	7.8	13.3	10.4	25.2	39.2	33.7
Commercial												
Charbagh	162.3	286.9	230.9	85.5	141.3	119.2	11.7	20.1	14.4	39.3	57.0	48.8
Alambagh	150.0	251.3	209.4	62.7	128.1	104.7	11.2	18.6	14.6	33.6	45.9	39.5
Aminabad	124.6	303.7	203.3	61.2	147.5	102.6	9.4	15.9	12.0	27.4	46.5	37.1
Chowk	188.7	345.9	276.7	87.8	141.8	114.3	9.2	17.4	12.4	34.9	63.8	51.1
Industrial												
Amausi	158.3	353.2	238.3	78.7	162.7	111.3	10.3	13.5	11.9	34.0	43.4	45.3
NAAQS	100			60			80			80		
WHO Guidelines	50			25			20*			40*		

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

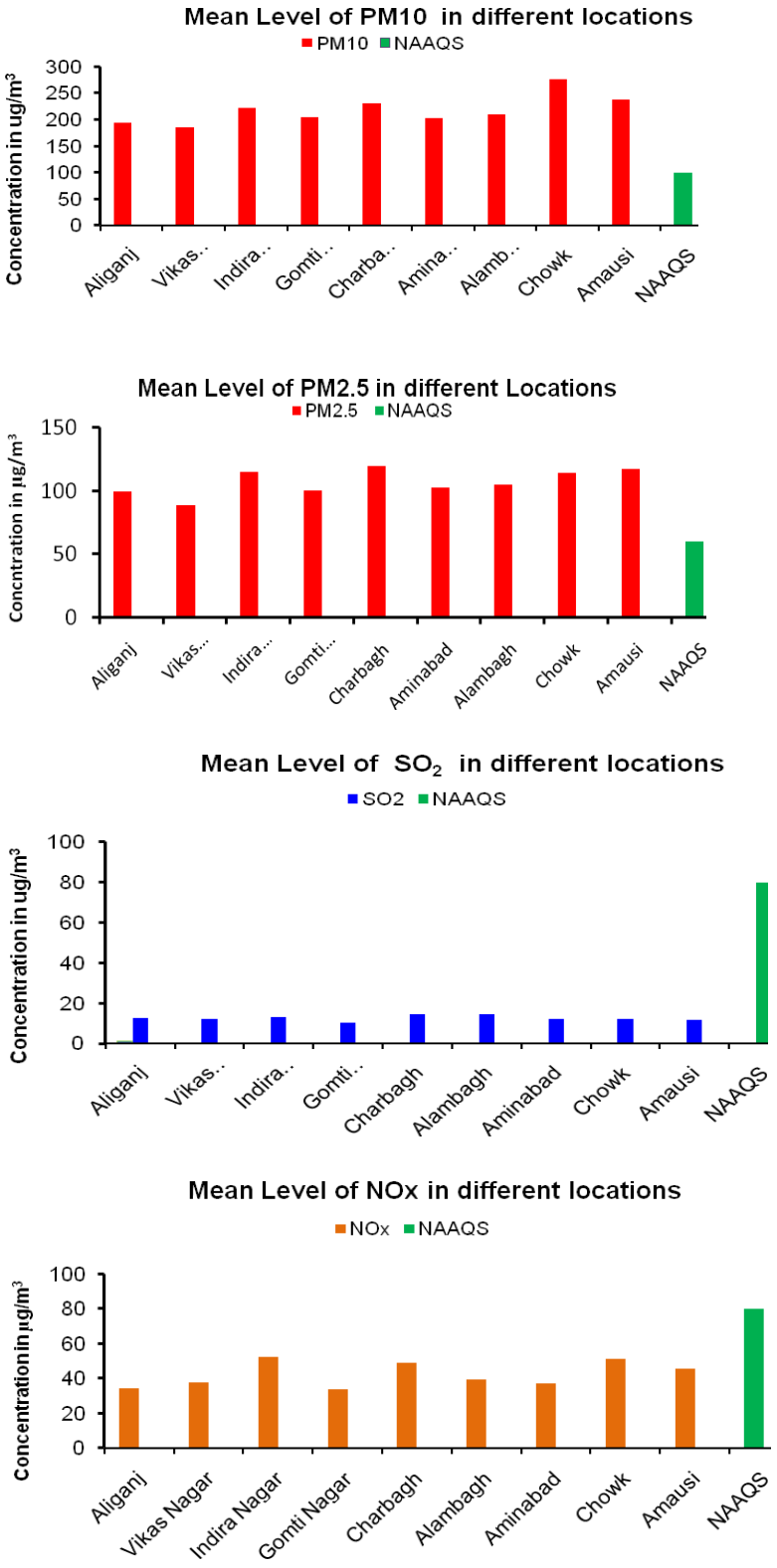

Fig 2: Concentration (µg/m^3) of PM_{10}, $PM_{2.5}$, SO_2 and NO_x in different areas of Lucknow city during pre monsoon season (2016) and compared with prescribed National Ambient Air Quality Standard (NAAQS)

1.3.5 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 presented in Table 9.

The 24 hr mean concentration of metals were found to be Pb = 124.52 (46.06 - 426.04) and Ni = 39.51 (21.13 – 53.34) ng/m^3.

Table -9: Metal Concentration in ng/m^3 associated with PM_{10}

Sl. No.	Location	Lead(Pb)	Nickel (Ni)
1	Aliganj	46.06	39.40
2	Vikas Nagar	79.56	38.33
3	Indira Nagar	100.22	50.32
4	Gomti Nagar	170.26	21.13
5	Charbagh	59.50	33.88
6	Alambagh	58.40	43.72
7	Aminabad	88.55	38.61
8	Chowk	**426.04**	53.34
9	Amousi	92.07	36.86
Mean		**124.52**	**39.51**
NAAQS		**1000**	**20***

N= 1, *=Annual Average

1.3.6 Noise

The monitoring data recorded during the pre monsoon period (May, 2016) is presented in Table 10.

In residential areas, the day and night time noise levels were recorded between 70.1 to 75.7 and 56.6 to 62.3 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 72.1 to 76.6 and 55.8 to 70.9 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 71.6 and 67.9 dB(A) respectively. Noise levels at industrial area in the day and night time was found below the prescribed limits of 75.0 and 70.0 dB(A) respectively.

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

Sl. No.	Area	Location	Noise level dB(A)	
			Day	Night
1	**Residential**	Aliganj	70.1	58.5
		Vikas Nagar	71.8	56.6
		Indira Nagar	75.7	62.3
		Gomti Nagar	70.9	57.2
		Standard	**55.0**	**45.0**
2	**Commercial**	Charbagh	76.6	70.9
		Alambagh	75.5	61.5
		Aminabad	72.1	55.8
		Chowk	72.8	62.7
		Standard	**65.0**	**55.0**
3	**Industrial**	Amausi	71.6	67.9
		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 year data have been compared to find out the prevailing trend of air pollution in Lucknow city (Fig.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 (Aminabad and Chowk) and one industrial area when compared to the data of the previous year. All the values are higher than the NAAQS (Fig. 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 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 (Fig.4).

1.4.3 Sulphur Dioxide (SO_2)

The level of SO_2 during pre monsoon since 2013 is presented in Fig. 5 for all the locations.

In residential areas, lower concentrations of SO_2 were found at all locations (except Vikas Nagar) compared to that of the previous year. Among the commercial areas (except Alambagh), SO_2 values showed slightly higher value over the last year. Industrial area (Amausi) also showed decreasing trend over the last year. All the values of the present study were found to be lower than the NAAQS (Fig. 5).

1.4.4. Oxides of Nitrogen (NO_x)

The level of NO_x during pre monsoon since 2013 is presented in Fig. 5 for all the locations. Among the residential and commercial areas (except Indira Nagar) all the locations showed decreasing trend, 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. 6).

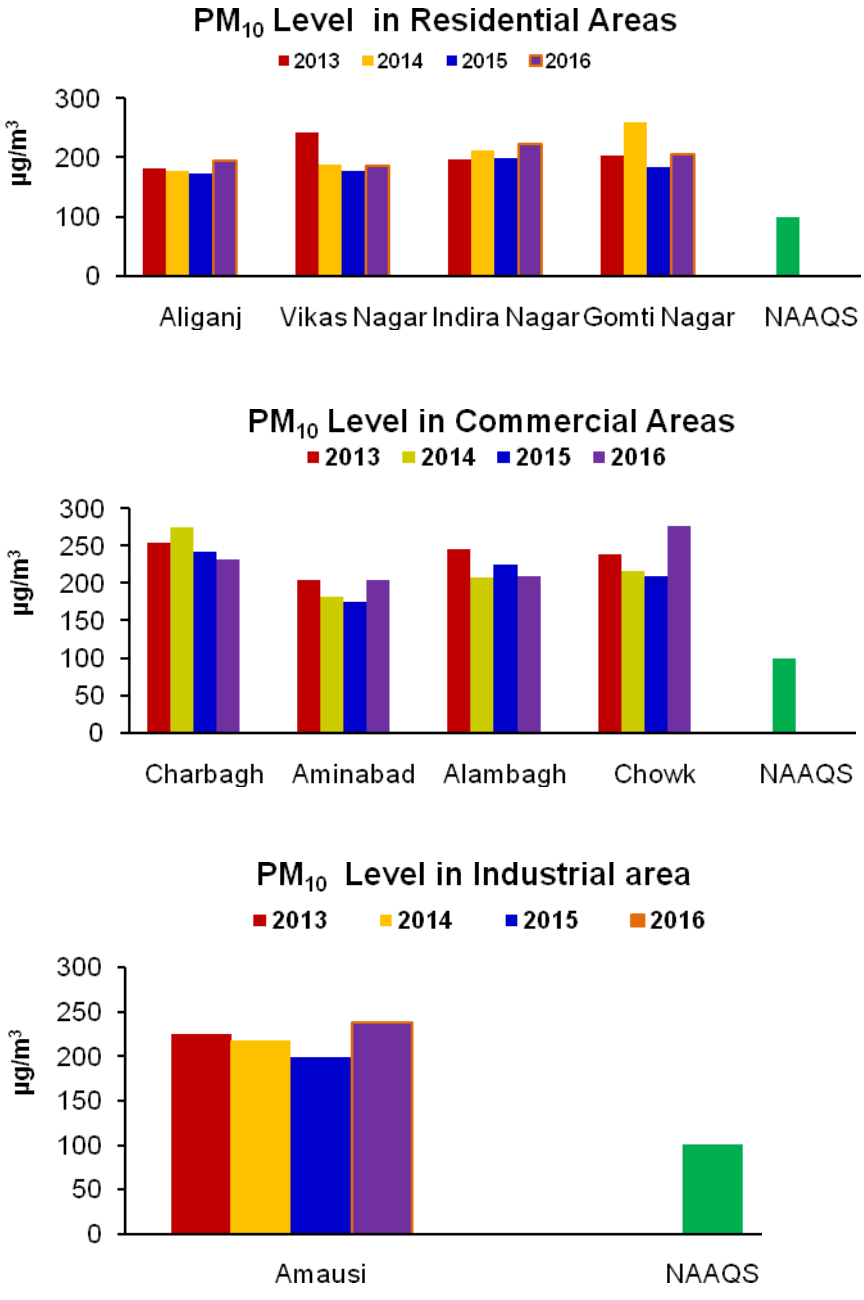

Fig 3: Concentration (µg/m^3) of PM_{10} **(**RSPM**)** in Residential, Commercial and Industrial areas of Lucknow city during 2013 to 2016 and compared with prescribed National Ambient Air Quality Standard (NAAQS)

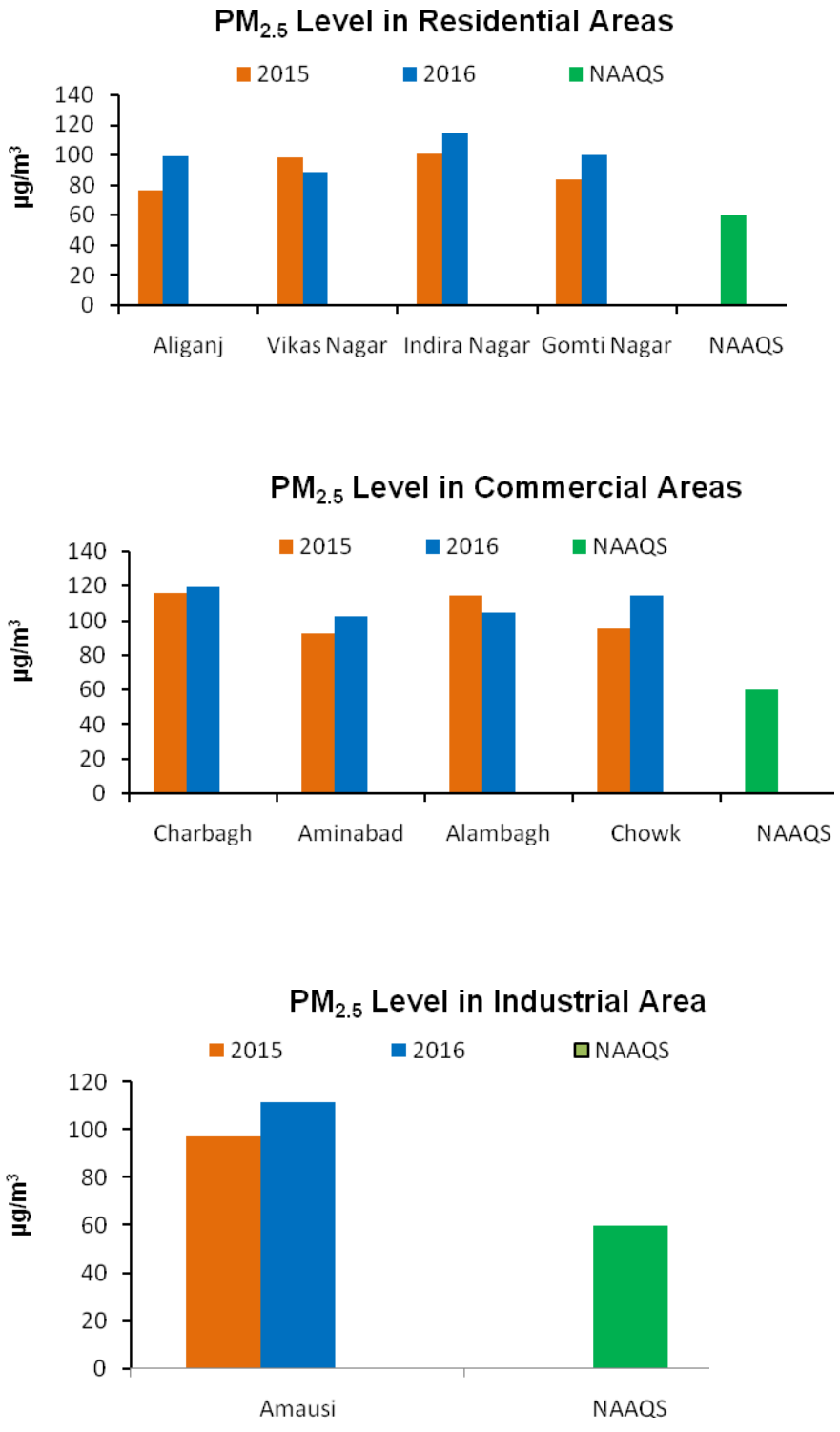

Fig 4: Concentration (µg/m^3) of $PM_{2.5}$ in Residential, Commercial and Industrial areas of Lucknow city during 2015 to 2016 and compared with prescribed National Ambient Air Quality Standard (NAAQS)

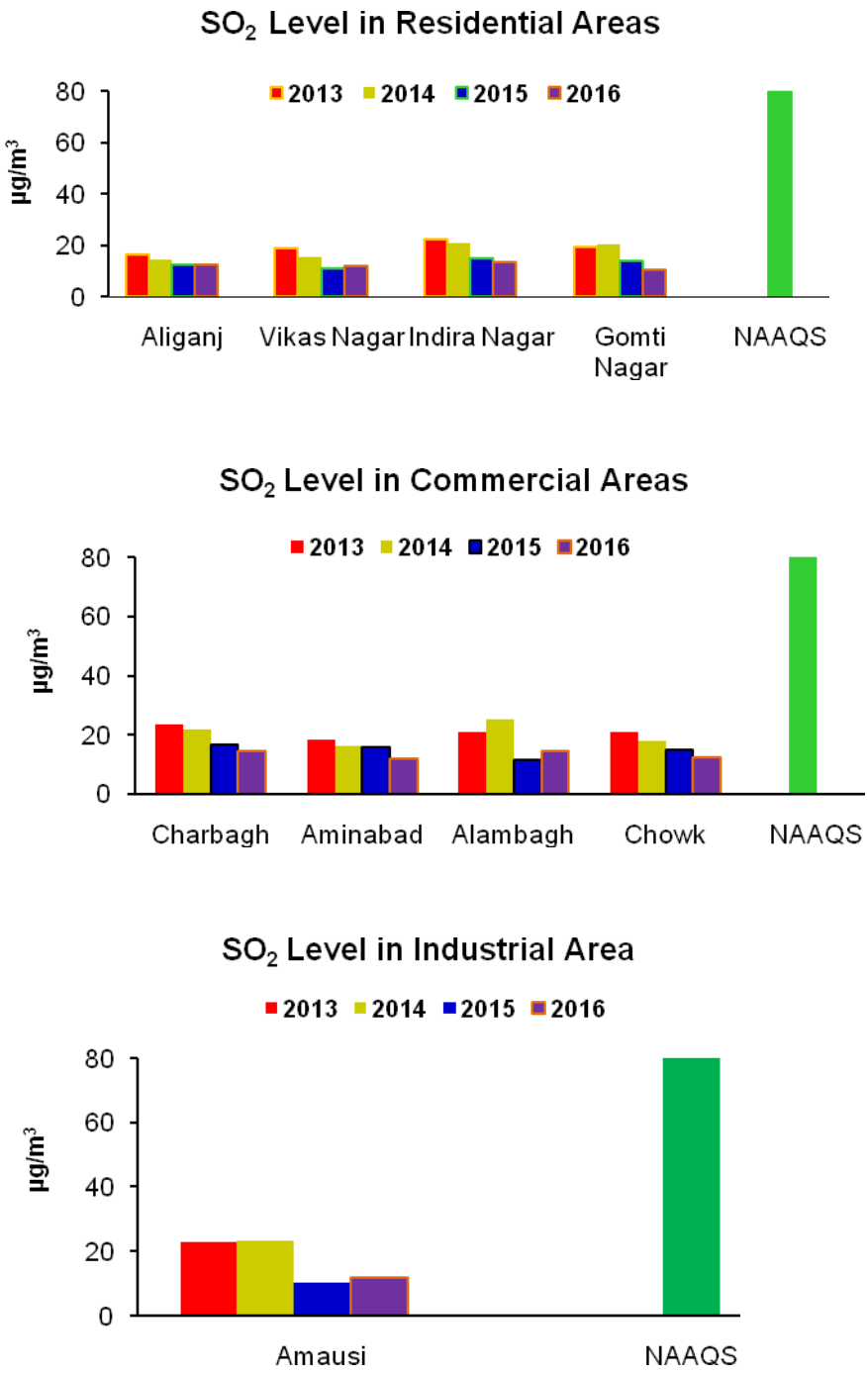

Fig 5: Concentration (µg/m^3) of SO_2 in Residential, Commercial and Industrial areas of Lucknow city during 2013 to 2016 and compared with prescribed National Ambient Air Quality Standard (NAAQS)

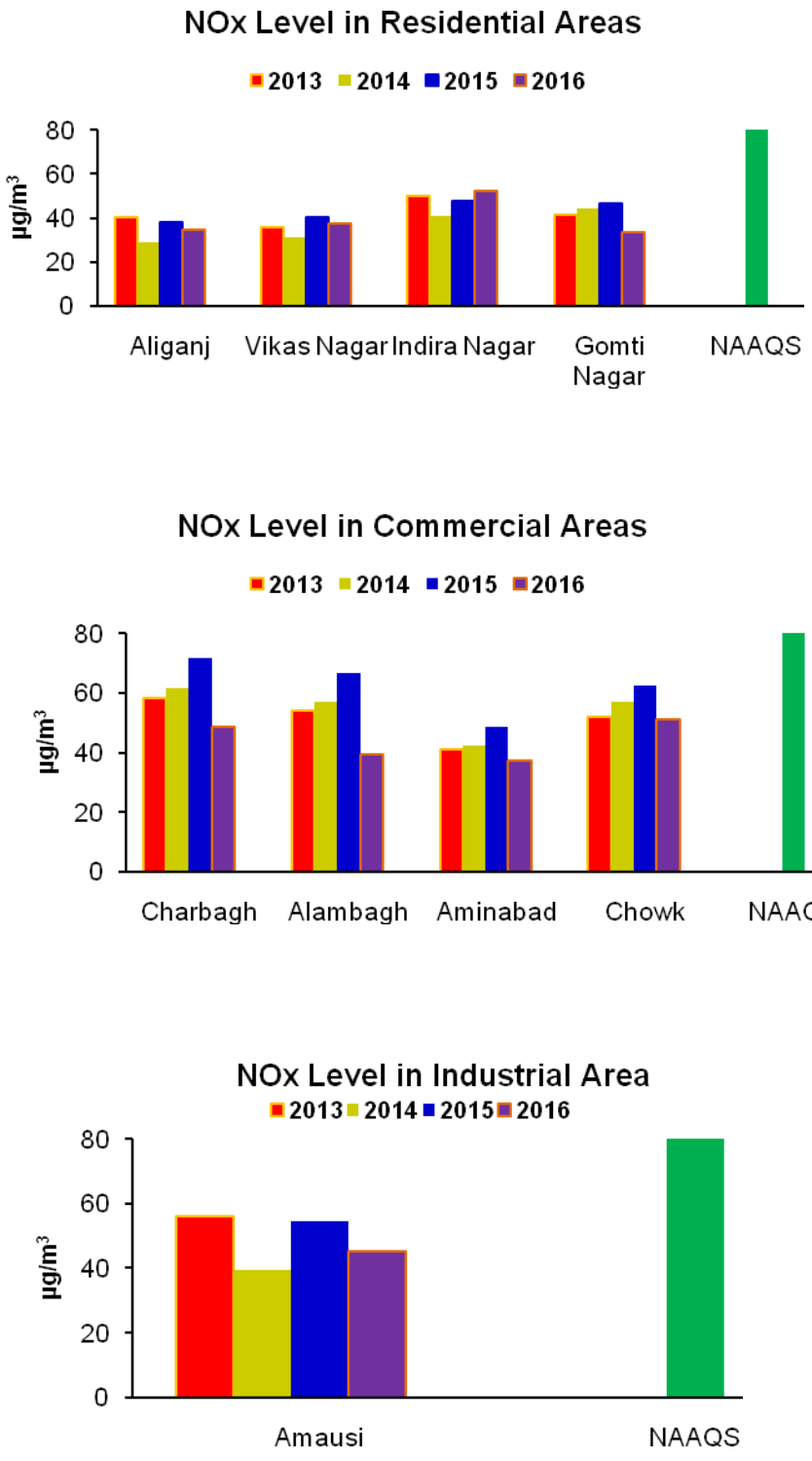

Fig 6: Concentration (µg/m^3) of NO_x in Residential, Commercial and Industrial areas of Lucknow city during 2013 to 2016 and compared with prescribed National Ambient Air Quality Standard (NAAQS)

1.4.5 Noise Level

Current year's noise data was compared with the corresponding data of the previous three years (2013 to 2015) and presented in Fig. 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 increasing trend over that of the previous year except Gomti 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 Fig. 7.

1.4.5.2 Night time Noise Level

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

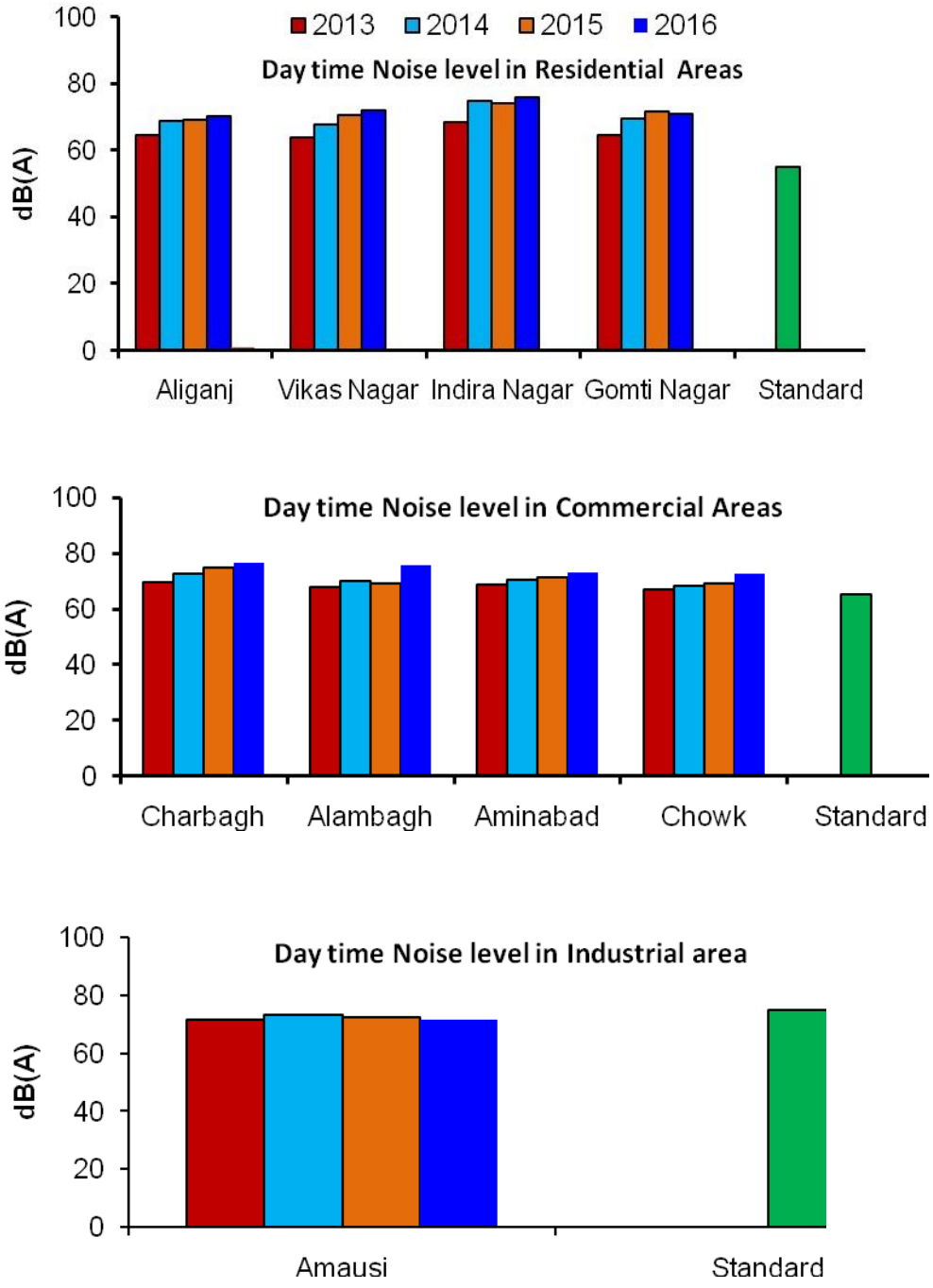

Fig 7: Comparison of day time Noise Level dB(A) in different areas of Lucknow city (2013-2016)

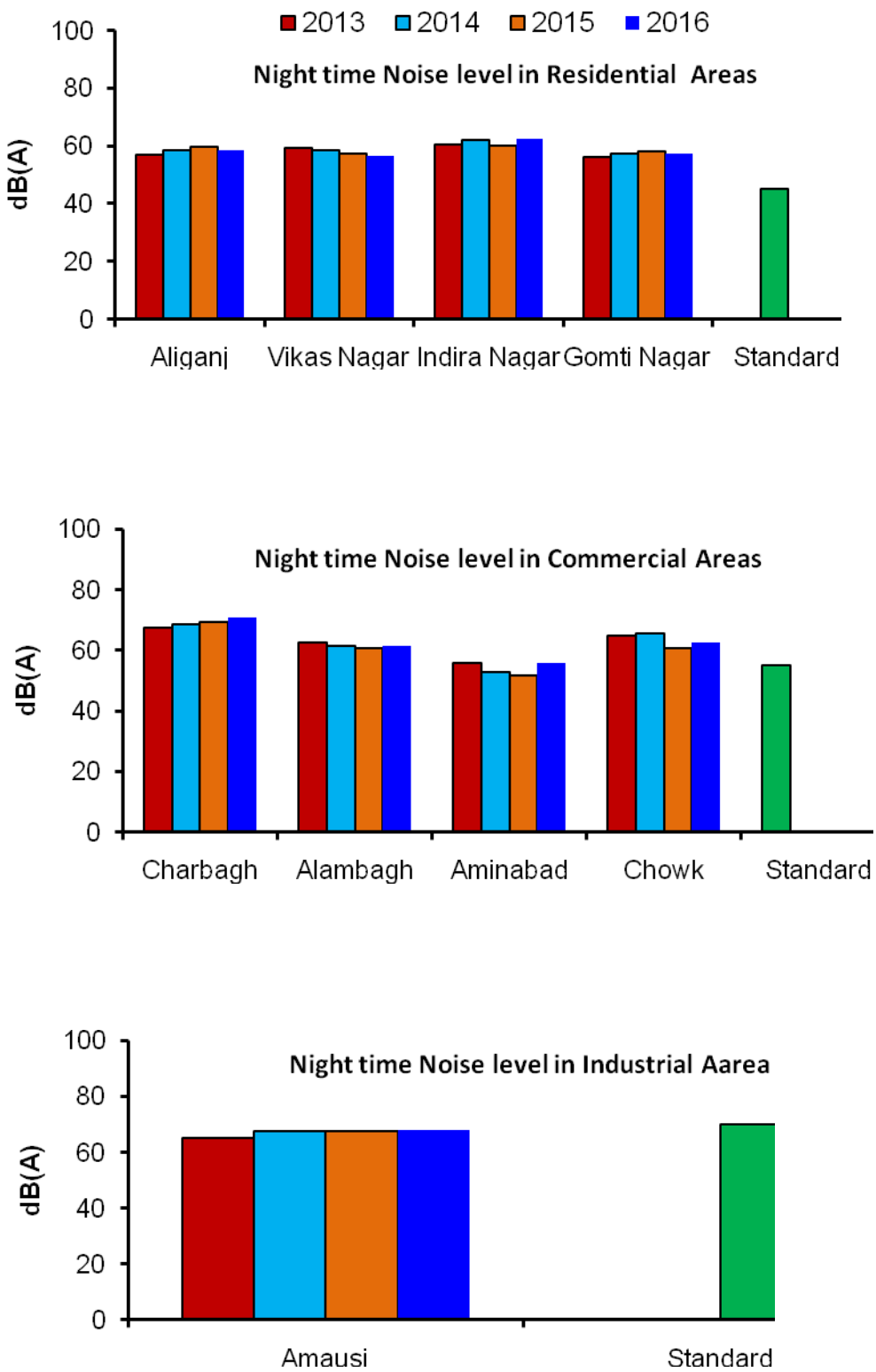

Fig 8: Comparison of night time Noise Level dB(A) in different areas ofLucknow city (2013-2016)

1.5 HEALTH EFFECTS

At elevated levels, all the 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 $\leq$ 10 μm and diameter $\leq$ 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)

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

- 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 Elements (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 NO_x 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), 2016 we have monitored air pollutants such as PM_{10}, $PM_{2.5}$, SO_2, NO_x 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 highlights of our study are 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 Particulates ($PM_{2.5}$) at all the monitoring locations of residential, commercial and industrial areas was higher than the NAAQS.

- 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.

- 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 in residential and commercial areas during day and night time showed higher level than their permissible limits whereas in industrial area it was within the limits.

The average annual vehicle growth over the last decade in Lucknow was near about 10%. Every year more than 1.5 lakh new vehicles are added in Lucknow. These vehicles using different fuels namely petrol, diesel, LPG and CNG make the environment more complex regarding the air quality and their synergistic effects on the human health. Also the latest models with advanced technology that release invisible tailpipe pollutant (ultrafine particles) are still a debatable issue. Rampant construction in the city and its outskirts, movements of heavy vehicles carrying construction materials, garbage dumps and metro construction in the city are other major sources of air pollution. A number of trees in city and outskirts have been cut down, reducing the sink available to absorb the air pollution.

Accumulation of different pollutants and their exposure to human beings needs immediate attention of the policy makers, 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 monsoon monitoring survey might be of help to focus on the pollution level in Lucknow city and its probable consequences.

1.7 RECOMMENDATIONS

- Subsidized public mass transport (Bus, Metro, Monorail etc.) must be introduced/ strengthened to minimize use of personal vehicles.
- Improvement in traffic management.
- All encroachment should be removed for roadside and restoration foot path for pedestrians.
- Adequate parking facilities should be provided in busy and market places to avoid traffic jam.
- Major roads of the city should be widened as far as possible.
- Ban on burning of dry leaves, tyres or any other type of solid waste and arrangement for its proper disposal.
- Plantation of trees wherever possible in parks, open spaces and road side areas.
- Systematically develop residential complex at the periphery of the city with all facilities to reduce crowd from central areas of the city.
- Pressure horns to be removed from all vehicles and avoid use of horn/minimise.
- Public awareness programme of air pollution and its health effects, reduction of automobile pollution by proper maintenance of vehicles, driving skills.

Industrial Emission

Burning of Refuge (leaves, papers and rags materials)

Acknowledgements:

We the Members of Environmental Monitoring Division are grateful to Professor Alok Dhawan, Director, CSIR-IITR and Dr Mukul Das, Chief Scientist, CSIR-IITR, for permission for this study and continuous encouragement. We also acknowledge Analytical Chemistry Division, Regulatory Toxicology Group, CSIR-IITR, for analytical and technical support.

We express our sincere thanks to Mr. Sagir Ahmad Ansari, Regional Transport Officer and Ms. Ritu Singh ARTO, Administration, Transport Nagar, Lucknow, Mr. Virendra Kumar Verma, Regional Manager, Lucknow City Transport Services Limited, Gomti Nagar, Lucknow, Mr. Jitendra Kumar Sinha, Dy. Manager, Indian Oil Corporation, Lucknow, Mr. Anilesh Kumar, Sr. Manager (MKTG. Services) and Mr. B. K. Singh, Bharat Petroleum Corporation Ltd, Lucknow and Mr. Vishal Bajpai, Chief Regional Manager, Hindustan Petroleum Corporation Limited, Lucknow and Mr. B. Anand Reddy, Director Commercial, Green Gas Limited, Lucknow for providing us necessary vehicular and oil consumption data. We also express our sincere thanks to all who provided necessary facilities at different monitoring locations.