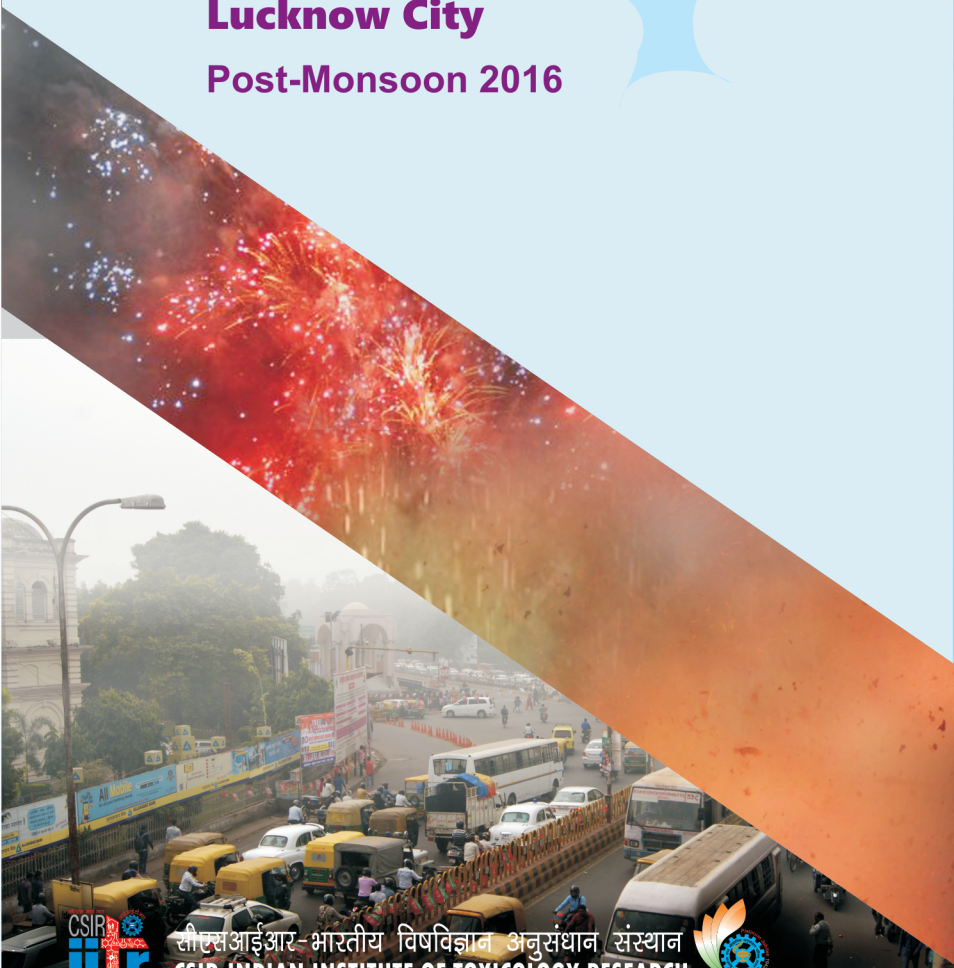
Assessment of Ambient Air Quality of

Lucknow City

Post-Monsoon 2016



सीएसआईआर-भारतीय विषविज्ञान अनुसंधान संस्थान

CSIR-INDIAN INSTITUTE OF TOXICOLOGY RESEARCH

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

PERSONNEL

Team Leader	:	Dr S. C. Barman
Co-Team Leader	:	Dr G. C. Kisku
		Er A. H. Khan
		Dr Jyotsna Singh
Other Participants (Technical)	:	Mrs Kalpana Padalia
		Mr Tajuddin Ahmed
		Mr Pradeep Shukla
		Mr Khalil Ahmed
Other Participants (Project Fellows)	:	Mrs Arpita Khare
		Mr Hamid Kamal
		Mr Ankur Dixit
		Mr Mohd. Irfan
		Ms Riddhi Rai

CONTENTS

Salient Features of the Study

❖ **Geographical Position of Lucknow**	**:**	26^{o} 52' N Latitude 80^{o} 56' E Longitude 128 m above sea level
❖ **Area (Metropolitan)**	**:**	310 sq. km.
❖ **Population (Metropolitan)**	**:**	28,15033 as per 2011 Census
❖ **Climate**	**:**	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 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) as on 31/03/2016**	**:**	125 outlets
❖ **Consumption of Petrol**	**:**	1,73,617 kl
❖ **Consumption of Diesel**	**:**	1,82,481 kl
❖ **Consumption of CNG**	**:**	3,02,4600 kg
❖ **Major Source of Pollution**	**:**	Automobiles, D. G. sets, industries and civil construction
❖ **Parameters Monitored**	**:**	PM_{10}, $PM_{2.5}$, $PM_{0.056}$ to PM_1, SO_2, NO_2, trace metals and noise level
❖ **Study Conducted by**	**:**	Environmental Monitoring Division CSIR-IITR, Lucknow

ASSESSMENT OF AMBIENT AIR QUALITY OF LUCKNOW CITY
POST-MONSOON, 2016

Environmental Toxicology Group, Environmental Monitoring Division,
CSIR- Indian Institute of Toxicology Research, Lucknow

1.0 SUMMARY

In our endeavor and commitment towards the national missions of Swachh Bharat and Swasth Bharat, CSIR-IITR conducted the environmental study to assess ambient air quality of Lucknow city. This study was carried out during 26th September to 26th October, 2016 (report of Diwali enclosed as Annexure-I) to assess the status of air quality by monitoring selected air pollutants namely respirable particulate matter (RSPM or PM_{10}), fine particulate matter ($PM_{2.5}$), sulphur dioxide (SO_2), nitrogen dioxide (NO_2) and noise level at nine representative locations, categorized as residential (four), commercial (four) and industrial (one) areas in Lucknow city. In addition, superfine and ultrafine particles were monitored at two more locations. The observed results revealed for 24 hourly PM_{10} level was found to be in the range of 60.1 to 398.2 µg/m^3 with an average of 197.8 µg/m^3. Whereas, 24 hours $PM_{2.5}$ level was found to be in the range 36.6 to 177.8 µg/m^3 with an average of 94.9 µg/m^3 regardless of locations. The average values of PM_{10} and $PM_{2.5}$ were found to be above the permissible limit (PM_{10} =100 and $PM_{2.5}$ = 60 µg/m^3) prescribed by Ministry of Environment and Forest, Government of India (MoEF, GOI) for these particles. 24 hours concentration of ultrafine particles (>PM_1 to $PM_{0.056}$) was 78.65 µg/m^3 in commercial and 43 µg/m^3 in rural area, so far no permissible limit prescribed by MoEF, GOI. 24 hours concentration of SO_2 and NO_2 were found in the range of 7.6 to 26.8 µg/m^3 and 23.7 to 98.7 µg/m^3 with an average concentration of 18.6 and 60.8 µg/m^3 respectively and all the values were below the permissible limits (80 µg/m^3). 24 hours mean level of trace metals; Ni & Pb which are associated with PM_{10} and *$PM_{2.5}$ fraction were found to be in the range of 27.8 to 98.9 ng/m^3 with an average of 58.9 ng/m^3 for Ni in PM_{10} and for $PM_{2.5}$ the range were 17.9 to 43.7 ng/m^3 with an average of 28.3 ng/m^3. All the Ni values were found to be above the permissible limit of annual average (20 ng/m^3). In case of Pb, 24 hours concentration in PM_{10} were found to be in the range of 64.3 to 886.0 ng/m^3 with an average of 202 ng/m^3 and similarly for $PM_{2.5}$, Pb level were found to be in the range of 32.5 to 112.5 ng/m^3 with an average of 59.6 ng/m^3. Pb level was found to be within the permissible limit (1000 ng/m^3). Noise levels during day and night times were found to be in the range of 66.4 to78.8 dB(A) and 56.3 to 69.6 dB(A) respectively, which were above the prescribed limits (day and night time noise levels in residential area are 55 and 45 dB(A)) and corresponding values for*

commercial area are 65 and 55 dB(A) respectively. In industrial area noise levels were recorded 68.9 and 65.1 dB(A) during day and night time which were less than its respective limits of 75 and 70 dB(A). Overall, our report is indicating an alarm on the substantial level of air pollution impacting Lucknow city environment and ultimately affecting its human health. It is suggested that major steps be initiated immediately to control the ambient air pollution for the safe future of the citizens of the Lucknow and Uttar Pradesh.

1.1 INTRODUCTION

Urban air pollution, now-a-days is one of the serious issues, because of the elevated levels of air pollutants in the ambient air causing environmental impacts and severe health effects on human beings. In developing countries, the large numbers of urban population in worldwide are exposed to high levels of air pollutants. Such levels of air pollution have drawn attention towards regular monitoring and mitigation of city air quality. There are several sources of air pollutants in urban areas such as tail pipe emission from vehicles, gensets, industrial operations, burning of solid wastes from urban kitchen, re-suspension of soil, etc. These sources generally generate a number of pollutants in the air namely particulate matter (PMs), sulphur dioxide (SO_2), nitrogen dioxide (NO_2) and other inorganic (trace elements) and organic pollutants poly aromatic hydrocarbon (PAHs) etc. Major sources of these pollutants are arising due to burning of fossil fuels [petrol, diesel, compressed natural gas (CNG), liquefied petroleum gas (LPG), coal, etc.]. Due to change of technologies and change of fuel consumption patterns, the composition ratio of each pollutant is changing over time. The changing scenario demands continuous assessment of air quality as well as its health effects. Pollutants released in the ambient environment interact with other existing pollutants and micrometeorological factors may form more intricate pollutants and that are more harmful to human health. So it is necessary to identify the pollutants, their source of transformation as well as levels of each pollutants and their impact on environment including living beings.

Several studies have been reported regarding health effects due to higher level of air pollutants, namely respiratory diseases and cardiovascular diseases. Research has been conducted in the areas on cardiology, immunology, hematology, etc. to assess the impact of air pollution. Most of the reports are based on people hospitalized in the polluted areas. It is very difficult to quantify the effect of individual pollutants in natural environment. In the environment, there are a number of pollutants present at different levels which are even at lower levels may not be harmful immediately but prolonged exposures may cause very serious issues. Indeed, there is a need of the hour for detailed investigation with respect to pollutant levels, sources, behavior in particular environment, seasonal and diurnal variation, fate in the environment,

threshold value (depends on number of factors), synergistic and cumulative effects and receptor part in the human body systems etc.

Lucknow, the capital city of Uttar Pradesh state is fast growing city. In the seventies and eighties the development of city begins in the Trans-Gomti area. At that time, large colonies like Indira nagar, Gomti nagar, Aliganj, Nirala nagar etc. all came into existence. Over the years these areas became saturated. Thus new bypass roads such as the one from Institute of Engineering and Technology (IET) to Polytechnic was constructed to connect Sitapur road to Faizabad road. Subsequent development began on the land available along this bypass road. Second bypass road was constructed to connect Sitapur road to Kanpur road at Awadh hospital via Indian Institute of Management (IIM), Dubagga crossing and Mohan road. Further, another bypass road Shaheed path was completed in 2005 which connects Faizabad road to Sultanpur road, Raibareli road and is terminated at Kanpur road near Airport. The area along all the by-pass roads have witnessed rapid development and hundreds of multi-storey apartments, villas, shopping complexes, international cricket stadium, schools and colleges.

City is facing problem of intercity vehicular traffic passing through its internal roads that contribute to a great extent to the existing air and noise pollution levels in the city. Therefore, to avoid the entry of these vehicles into the city a proposal for 108 km long outer ring road has been initiated in 2015 and its construction would begin early next year (2017). This outer ring road will join Sitapur road, Faizabad road, Sultanpur road, Raibareli road and Kanpur road. Therefore for better traffic management all the connecting roads including Arjunganj-Cantt area (Sultanpur highway), Deva road, Kursi road, Faizabad road, Mohan road, Bijnaur road will be widened as per the requirements from a width of 60 to 76 m.

Development continued on the outskirts of the city around the bypass road and other outgoing roads. Many colonies were developed beyond corporation limits and corporation has extended its services to some of these areas. The demand for new infrastructural facilities in the city still exists. Recently, Lucknow corporations submitted a proposal to state government to include about 81 villages in corporation limits. Prior to this proposal the corporation limit was expanded in 1987. Once the

proposed expansion is effective the number of villages in corporation limit will increase from 124 to 205 and its area will increase from 310 sq. km to 400 sq.km. Lucknow Development Authorities (LDA) has come up with the master plan 2031 in which 197 villages will become a part of the city and its area will increase to 1050 sq. km. LDA will prepare the zonal development plan for these 197 villages which would include roads connectivity, bus station, public facilities and will also decide the land use pattern. The land use conversion of Malihabad phal patti (mango garden) and other green belt areas around the city needed to be planned considering the environmental aspects.

Lucknow city has a population of 28.15 lakh (Municipal Corporation + Cantonment) as per 2011 census and an area of 310 sq. km. Vehicular traffic is the main source of particulate air pollution in Lucknow city. Continuous emission of pollutants from vehicular traffic adversely affects the ambient air quality as well as the health of human beings. The number of different categories of vehicles registered with RTO (regional transport office), Lucknow is 18,64,556 **(**as on 31st March, 2016) which is 9.06% higher than the last year (Table 1). Uttar Pradesh State Road Transport Corporation (UPSRTC) introduced bus services under the banner "Lucknow Mahanagar Parivahan Sewa" 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 companies (Table 3) as on 31st March, 2016.

As per Oil marketing companies Indian oil corporation (IOC), Bharat petroleum corporation limited (BPCL), Hindustan petroleum corporation (HPCL)] the consumption/sale of petrol and diesel was 1,73,617 and 1, 82,481 kl as on 31st March, 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 six CNG filling stations and consumption of CNG during 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.

Presently the city has more than 18 lakh vehicles which are increasing at an average annual growth rate of about 9%. Also the huge ongoing construction activity including metro rail construction, roads and flyover construction, and multi-storey apartment construction, have been contributing to the air pollution in addition to the domestic, commercial, industrial and vehicular sources in the city. Considering all the factors, assessment of the ambient air quality of Lucknow city was carried out at eleven locations during post-monsoon (September-October), 2016 with respect to PM_{10}, $PM_{2.5}$, SO_2, NO_2, fine particles and noise level with the following aims and objectives:

- *To assess levels of air pollutants such as PM_{10}, $PM_{2.5}$, superfine & ultrafine particles, SO_2, NO_2, trace metals and noise level.*
- *To analyse the trends of pollutants over a period of time in Lucknow city.*
- *To assess day and night time noise level to ensure compliance of permissible noise levels.*
- *To create a database for environmental planning.*
- *To create public awareness about environmental pollution.*

Table 1: Vehicles registered with RTO Lucknow during 2014-15 and 2015-16.

Sl. No.	Type of vehicle	Number of registered vehicles on 31st March 2016*		% Change
		2014-15	2015-16	
1	Multi articulated vehicles	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.	Route details*	No. of buses	Frequency
1	11	BBD – Chinhat - Gomti nagar - Alambagh 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	18	10 minutes interval
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 – Vikas nagar – Nishatganj -Sikandrabad - Hussaingaj - Alambagh - Rajnikhand Gudamba - Badshanagar - Avadh hospital	17	10 minutes interval
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 P.G.I.	SGPGI - Telebagh - Alambagh - Charganj - Hussainganj - GPO - Mahanagar - Engineering college.	1	180 minutes
14	33 L.U.	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	

**Source: Lucknow City Transport Services Limited.*

Table 3: Fuel outlets in Lucknow city.

Sl. No.	Agency	Number of outlets as on 31st March 2016*
1	Indian Oil Corporation	51
2	Bharat Petroleum Corporation Ltd.	38
3	Hindustan Petroleum Corporation Ltd.	27
4	Compressed Natural Gas stations	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	% Cha-nge	Apr.14 to Mar. 15	Apr.15 to Mar.16	% Cha-nge	Apr. 14 to Mar. 15	Apr. 15 to Mar.16	% Cha-nge
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	Years/ Number*		% 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 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 is given in Table 7. In addition, superfine and ultrafine particles were monitored at two more locations (CSIR-IITR M.G. road campus and CSIR-IITR Gheru campus) of Lucknow city.

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
6	Alambagh	Commercial
7	Aminabad	Commercial
8	Chowk	Commercial
9	Amausi	Industrial
10	CSIR-IITR M.G. road campus	Commercial
11	CSIR-IITR Gheru campus	Rural

Table 7: Parameters and methodology for air quality monitoring

Sl. No.	Parameters	Time Weighted average	Methods
1	Particulate matter: PM_{10} and $PM_{2.5}$	24 hours	Gravimetric
2	Sulphur dioxide (SO_2)	24 hours	Improved West Gaeke
3	Nitrogen dioxide (NO_2)	24 hours	Modified Jacob & Hochhesier (Sodium Arsenite)
4	Noise level	1 hour	The measurement of noise level was carried out during: Day (6 AM to 10 PM) and Night (10 PM to 6 AM) using noise level meter

1.3 RESULTS

The detailed results of air quality monitoring collected during 26th September to 26th October, 2016 are presented in Table 8 and Figure 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 162.8 to 216.8 $\mu g/m^3$ with an average of 180.8 $\mu g/m^3$. In commercial areas (Charbagh, Alambagh, Aminabad and Chowk) the average concentrations of PM_{10} in the range of 179.7 to 264.8 $\mu g/m^3$ with an average of 211.1 $\mu g/m^3$. In industrial area (Amausi), the average concentrations of PM_{10} were 212.9 $\mu g/m^3$. The maximum 24 hours mean concentration of PM_{10} was observed in Vikas nagar (302.7 $\mu g/m^3$) in residential area and Chowk (398.2 $\mu g/m^3$) in commercial area. All the location, mean values of PM_{10} were found above the prescribed National Ambient Air Quality Standard (NAAQS-2009) of 100 $\mu g/m^3$ for industrial, residential, rural and other areas.

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 $PM_{2.5}$ in the range of 79.6 to 114.9 $\mu g/m^3$ with an average of 91.0 $\mu g/m^3$. In commercial areas (Charbagh, Alambagh, Aminabad and Chowk) the average concentrations of $PM_{2.5}$ were in the range of 78.4 to 114.5 $\mu g/m^3$ with an average of 97.5 $\mu g/m^3$ respectively. In industrial area (Amausi), the average concentration of $PM_{2.5}$ was 99.6 $\mu g/m^3$. The maximum 24 hours mean concentration of $PM_{2.5}$ was observed in Indira nagar (151.2 $\mu g/m^3$) in residential area and Charbagh (177.8 $\mu g/m^3$) in commercial area. Overall, mean values of $PM_{2.5}$ at all the locations were above the prescribed standards of NAAQS-2009 of 60 $\mu g/m^3$ for industrial, residential, rural and other area.

1.3.3 Sulphur dioxide (SO_2)

In residential area (Aliganj, Vikas nagar, Indira nagar and Gomti nagar) the mean level of SO_2 was in the range of 16.6 to 21.4 μg/m^3 with an average of 18.2 μg/m^3. In commercial area (Charbagh, Alambagh, Aminabad and Chowk) the average concentration of SO_2 was in the range of 17.4 to 21.3 μg/m^3 with an average of 19.3 μg/m^3. In industrial area (Amausi) the average concentration of SO_2 was 16.7 μg/m^3. All the values of SO_2 were well below the prescribed standard of NAAQS-2009 (80 μg/m^3) in all the locations.

1.3.4 Nitrogen dioxides (NO_2)

In residential areas (Aliganj, Vikas nagar, Indira nagar and Gomti nagar) the 24 hours average concentrations of NO_2 was found in the range of 47.9 to 70.4 μg/m^3 with an average of 56.7 μg/m^3. In commercial areas (Charbagh, Alambagh, Aminabad and Chowk) the average concentrations of NO_2 was found in the range of 54.5 to 79.1 μg/m^3 with an average of 66.4 μg/m^3. In industrial area (Amausi) the average concentration was 55.6 μg/m^3. All the values of NO_2 were within the prescribed NAAQS of 80 μg/m^3 in all the monitoring locations except the commercial location (Charbagh).

1.3.5 Superfine particles ($PM_{0.56}$, $PM_{0.32}$, $PM_{0.18}$)

The monitoring of superfine particles were conducted during the month of October, 2016 at two locations i.e. city commercial centre (CSIR-IITR main campus) and in rural area (CSIR-IITR Gheru campus) are reported in Table 9. The 24 hours mean concentrations of PM_1, $PM_{0.56}$, $PM_{0.32}$ and $PM_{0.18}$ were found to be 18.29, 15.48, 12.48 and 12.36 μg/m^3 respectively and total particulate level was 58.59 μg/m^3 in city commercial area. Similarly the same values for village/ rural area were 10.22, 9.11, 6.69 and 6.12 μg/m^3 respectively with total value was 32.13 μg/m^3. Average concentration of particulate matter in fine and superfine sub-fractions was higher in commercial area of Lucknow city as compared to rural area (Figure 2). Maximum concentration of particle was in the range of $PM_{1.0}$ while lowest in $PM_{0.056}$ sub-fractions.

1.3.6 Ultrafine particles ($PM_{0.1}$, $PM_{0.056}$)

The 24 hours mean concentration of $PM_{0.1}$ and $PM_{0.056}$ was found to be 11.44 and 8.61 μg/m^3 respectively and the total particulate in this range was 20.05 μg/m^3 for city

commercial area. Similarly in rural area concentration was 6.19 and 4.69 μg/m^3 respectively and total value of these particles was 43 μg/m^3 (Table 9). The sub-fractions of fine and ultrafine particles clearly showed that quantity of particulate matter decreased with the size. Maximum concentration of particle was in the range of $PM_{1.0}$ while lowest in $PM_{0.056}$ sub-fractions. Concentrations of ultrafine particles were found to be 20.05 μg/m^3 (24 h mean) in commercial area of Lucknow city, whereas in the rural area value of ultrafine particles was found to be 10.87 μg/m^3 (24 h mean). Average total concentration of ultrafine particles were found to be 20.05 μg/m^3 (24 hour mean) in commercial area of Lucknow city, whereas in the rural area value of ultrafine particles was found to be 10.87 μg/m^3 (24 hour mean). For these ultrafine particles, no International and National guideline is available at this time. Concentration of particulate matter in fine and superfine subfractions was higher in commercial area of Lucknow city as compared to rural area (Figure 3).

Table 8: Concentration (μg/m^3) of PM_{10}, $PM_{2.5}$, SO_2 and NO_2 during Post-monsoon, 2016.

Location	RSPM (PM_{10})			$PM_{2.5}$			SO_2			NOx		
	Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.
Residential												
Aliganj	84.4	260.2	162.8	45.3	108.2	79.6	8.8	22.6	17.8	26.5	65.2	52.8
Vikas nagar	60.1	302.7	175.0	38.8	134.5	87.5	8.3	18.9	16.2	23.7	60.7	47.9
Indira nagar	115.0	286.1	216.8	41.1	151.2	114.9	9.8	25.7	21.4	46.6	93.2	70.4
Gomti nagar	62.6	266.6	168.8	36.6	119.7	82.1	7.6	23.9	17.5	28.7	67.8	55.7
Commercial												
Charbagh	95.6	284.1	207.4	39.6	177.8	114.5	12.9	26.8	21.3	43.2	82.3	67.3
Alambagh	72.2	297.4	192.3	45.9	114.3	88.3	9.7	22.7	18.3	43.1	87.8	64.7
Aminabad	76.3	252.1	179.7	41.1	105.5	78.4	9.9	18.4	17.4	35.1	65.7	54.5
Chowk	137.3	398.2	264.8	51.3	162.1	108.9	11.7	25.4	20.1	40.6	98.7	79.1
Industrial												
Amausi	93.1	327.5	212.9	54.3	159.8	99.6	9.5	23.8	17.2	28.5	69.76	55.6
NAAQS-2009	100			60			80			80		
WHO Guidelines	50			25			20			40*		

No. of samples =6, *= Annual average and rest 24 hours, NAAQS=National Ambient Air Quality Standards

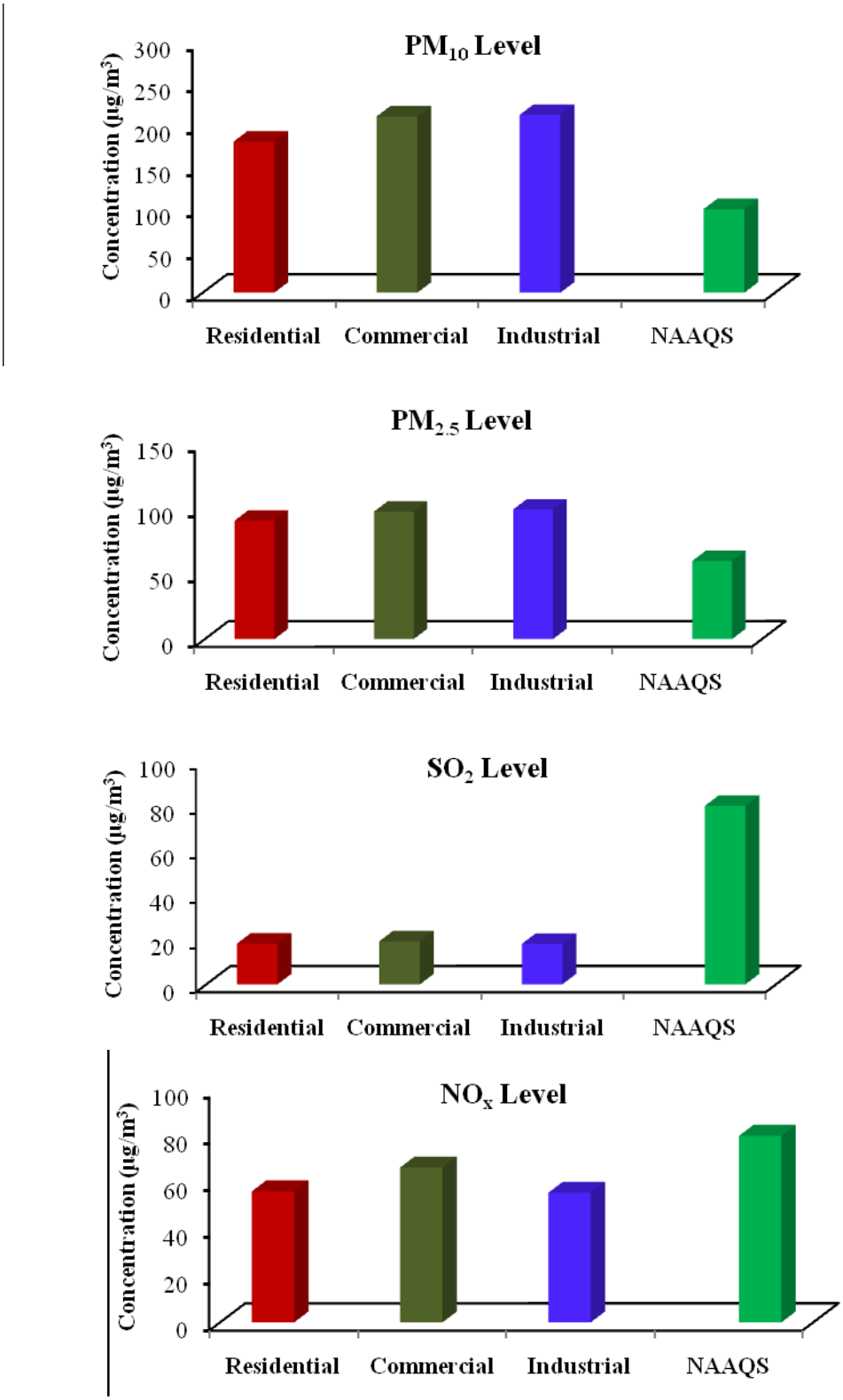


Figure 1: Concentration (µg/m^3) of PM_{10}, $PM_{2.5}$, SO_2 and NO_2 in different areas of Lucknow city during Post-monsoon season (2016) and compared with standard (NAAQS-2009).

Table 9: Minimum, maximum and average levels of particulate matter in fine and ultrafine sub-fractions (24 hours mean) during Post-monsoon 2016.

Particulate fractions	City commercial area (CSIR-IITR M.G. road campus)			Rural area (CSIR-IITR Gheru campus)		
	Min.	Max.	Avg.	Min.	Max.	Avg.
Fine particles (sub-fractions) (µg/m^3, 24 h mean)						
$PM_{1.0}$ (≤1µm)	14.32	21.76	18.29	7.69	11.89	10.22
$PM_{0.56}$ (≤0.56µm)	14.21	17.11	15.48	7.32	11.2	9.11
$PM_{0.32}$ (≤0.32µm)	7.6	15.2	12.48	5.8	7.34	6.69
$PM_{0.18}$ (≤0.18µm)	11.09	13.67	12.36	5.12	7.98	6.12
Total (fine)	51.36	66.08	58.59	27.34	37.37	32.13
Ultrafine particles (sub-fractions) (µg/m^3, 24 h mean)						
$PM_{0.1}$ (≤100nm)	9.12	14.1	11.44	4.32	7.74	6.19
$PM_{0.056}$ (≤56nm)	6.4	10.76	8.61	3.65	6.77	4.69
Total (UFPs)	17.05	22.44	20.05	7.97	12.57	10.87
Total (fine and UFP subfractions)	71.24	86.9	78.65	37.53	49.0	43.0

No. of samples = 4

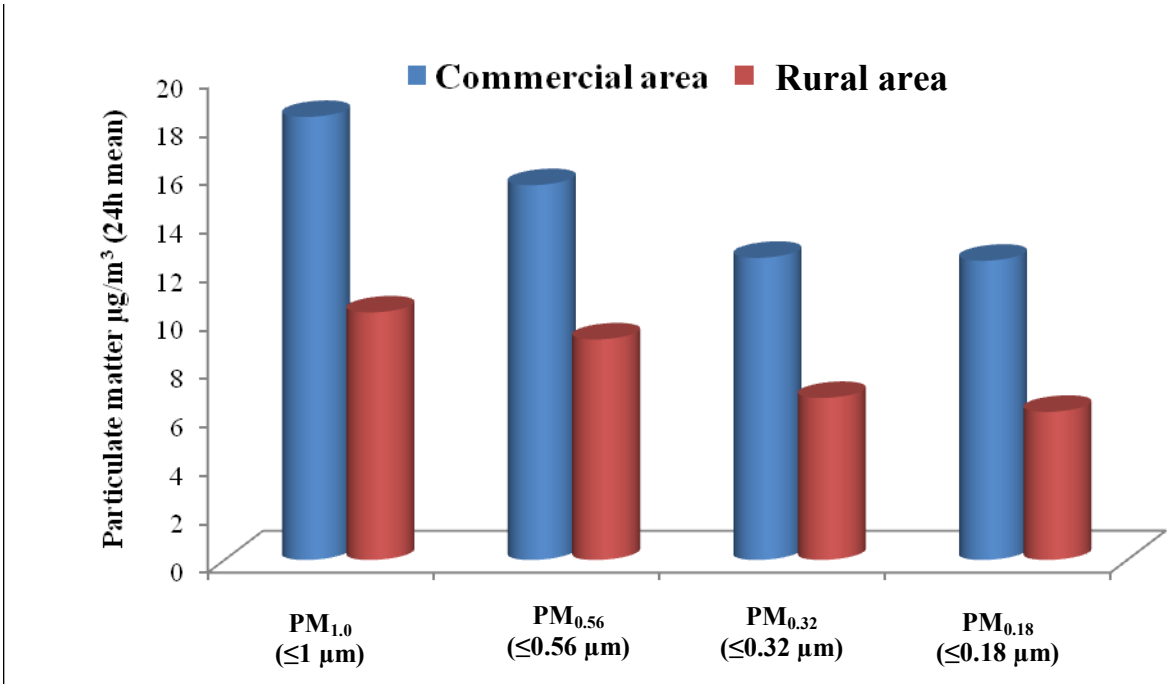


Figure 2: Post-monsoon levels (average) of particulate matter in fine particle sub-fractions.

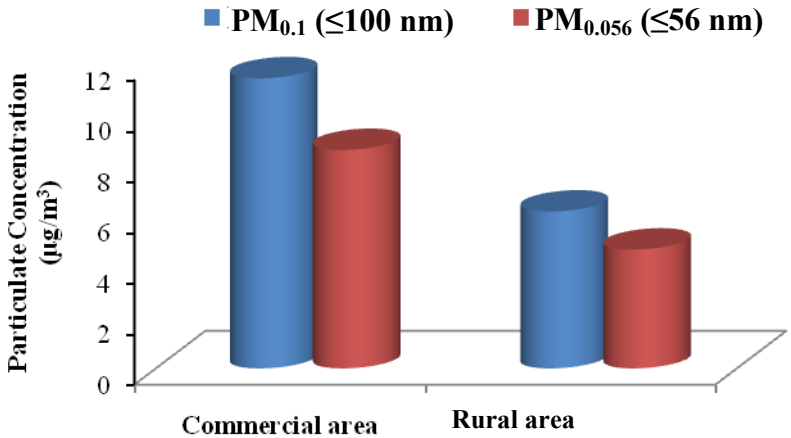


Figure 3: Post-monsoon levels (average) of particulate matter in ultrafine sub-fractions.

1.3.7 Trace metals in ambient air associated with RSPM or PM_{10} and $PM_{2.5}$

The trace metals (Ni and Pb) were estimated in the ambient air which are associated with PM_{10} and $PM_{2,5}$ at nine monitoring locations. The results are present in Table 10. The 24 hours mean concentration of metals in PM_{10} was found to be Ni = 58.1 (27.8-98.9) ng/m^3 and Pb = 202.0 (64.3-886.0) ng/m^3. Whereas, in $PM_{2.5}$, the 24 hours mean concentration was found to be Ni = 28.3, (17.9-43.7) ng/m^3 and Pb = 59.6 (32.5-112.5) ng/m^3.

Table 10: Metal concentration (ng/m^3) associated with PM_{10} and $PM_{2.5}$.

Locations	Pb		Ni	
	PM_{10}	$PM_{2.5}$	PM_{10}	$PM_{2.5}$
Residential Area				
Aliganj	64.3	39.8	75.9	32.0
Vikas nagar	107.9	77.3	27.8	23.3
Indira nagar	119.3	65.9	32.8	17.9
Gomti nagar	132.3	58.8	55.0	23.0
Average	105.95	60.45	47.87	24.05
Commercial Area				
Charbagh	75.1	48.3	68.0	43.7
Alambagh	121.6	52.3	36.9	19.9
Aminabad	109.3	32.5	41.2	32.8
Chowk	886.0	112.5	93.7	28.6
Average	298.0	61.4	59.8	31.3
Industrial Area				
Amausi	202.2	49.8	98.9	33.7
NAAQS-2009	*1000.0		** 20	

N= 1, NAAQS **Ni=Annual average; *Pb=24 hours average

1.3.8 Noise

The noise monitoring data recorded during the post-monsoon period is presented in Table 10. In residential areas, the day and night time noise levels were recorded between 66.4 to 70.2 dB(A) and 56.3 to 61.1 dB(A) respectively. All the values were higher than the prescribed limit of 55 dB(A) and 45 dB (A) for day and night time respectively. In commercial and heavy traffic area, the day and night time noise level were recorded between 72.5 to 78.8 dB(A) and 60.3 to 69.6 dB(A) respectively. Noise level at all the commercial sites during day and night time were found above the prescribed limit of 65 dB(A) and 55 dB (A) respectively. In industrial area (Amausi), the day and night time noise levels were recorded 68.9 dB (A) and 65.1 dB (A) respectively. Noise levels at all industrial locations in the day and night time was found below the prescribed limit 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	68.2	57.7
		Vikas nagar	66.4	56.3
		Indira nagar	70.2	61.1
		Gomti nagar	66.8	56.4
		Standard	55.0	45.0
2	Commercial	Charbagh	78.8	69.6
		Alambagh	73.2	64.8
		Aminabad	73.7	60.3
		Chowk	75.1	65.8
		Standard	65.0	55.0
3	Industrial	Amausi	68.9	65.1
		Standard	75.0	70.0

1.4 TRENDS OF AMBIENT AIR QUALITY IN LUCKNOW CITY

The observed PM_{10}, SO_2 and NO_2 for three years data and for $PM_{2.5}$ level from last year (2014-15) have been compared to find out the prevailing trend of air pollution in Lucknow city (Figures 4-6). The slight decrease or increase 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 all the locations in residential areas, lower values were found compared to the

previous year (Figure 4). Among the commercial areas, PM_{10} values were also found to be lower than the previous year (2015) except Chowk and industrial area. All the values observed for these areas are higher than the NAAQS-2009.

1.4.2 Sulphur dioxide (SO_2)

Concentration of SO_2 was found either slightly higher or maintained same level when compared to the previous years at all the residential area whereas in commercial and industrial areas showed lower value (Figure 5). All the values were found to be below the standard according to the NAAQS-2009.

1.4.3 Nitrogen dioxide (NO_2)

The level of NO_2 during post-monsoon from 2013 is presented in Figure 6. In residential area showed lower values than the previous years. In commercial and industrial areas, all the values showed lower than the previous year values except Chowk. All the values of the present study observed this year for NO_2 were found to be lower than the NAAQS-2009.

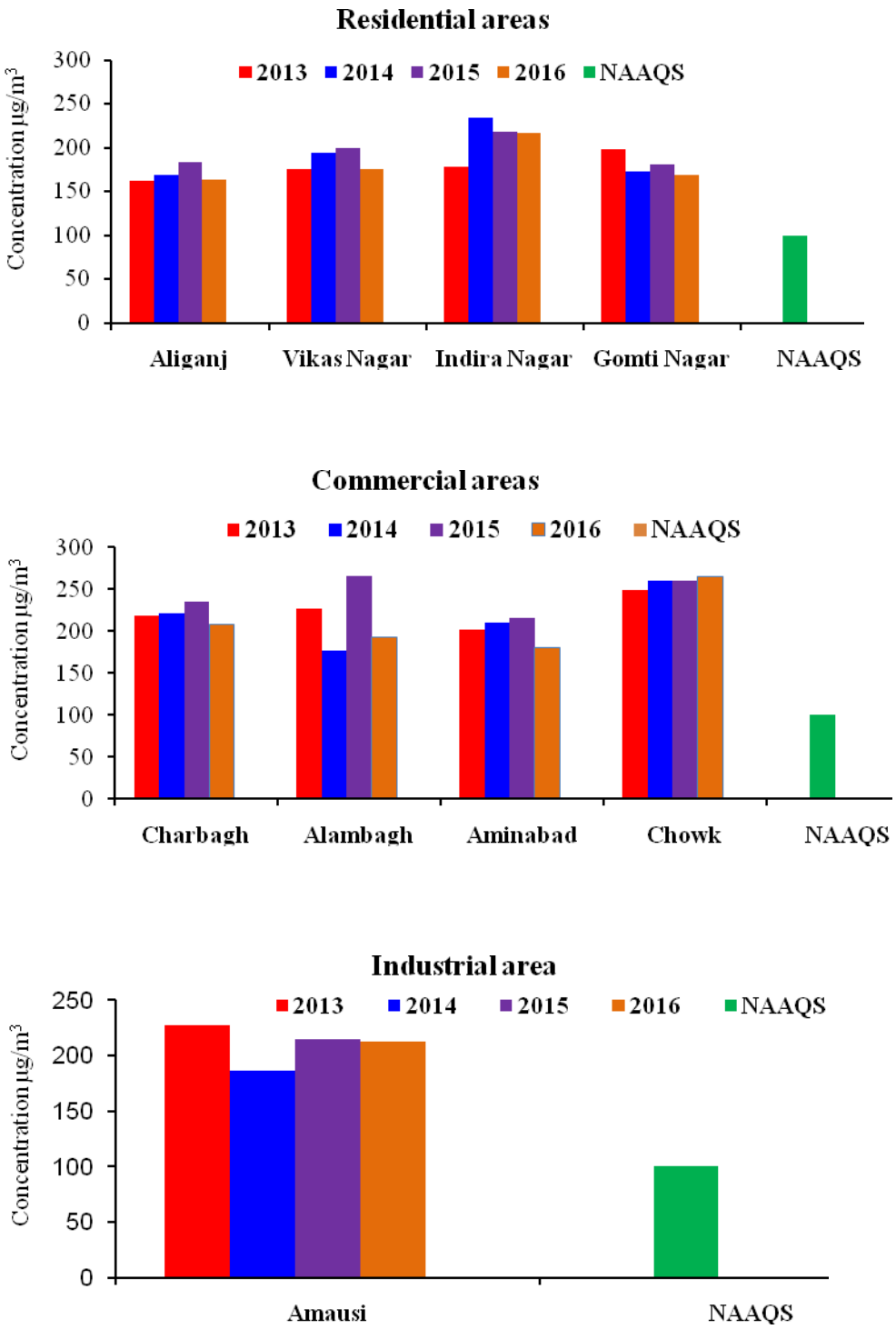


Figure 4: Concentration (µg/m^3) of PM_{10} (RSPM) in residential, commercial and industrial areas of Lucknow city during 2013 to 2016 and compared standard (NAAQS-2009).

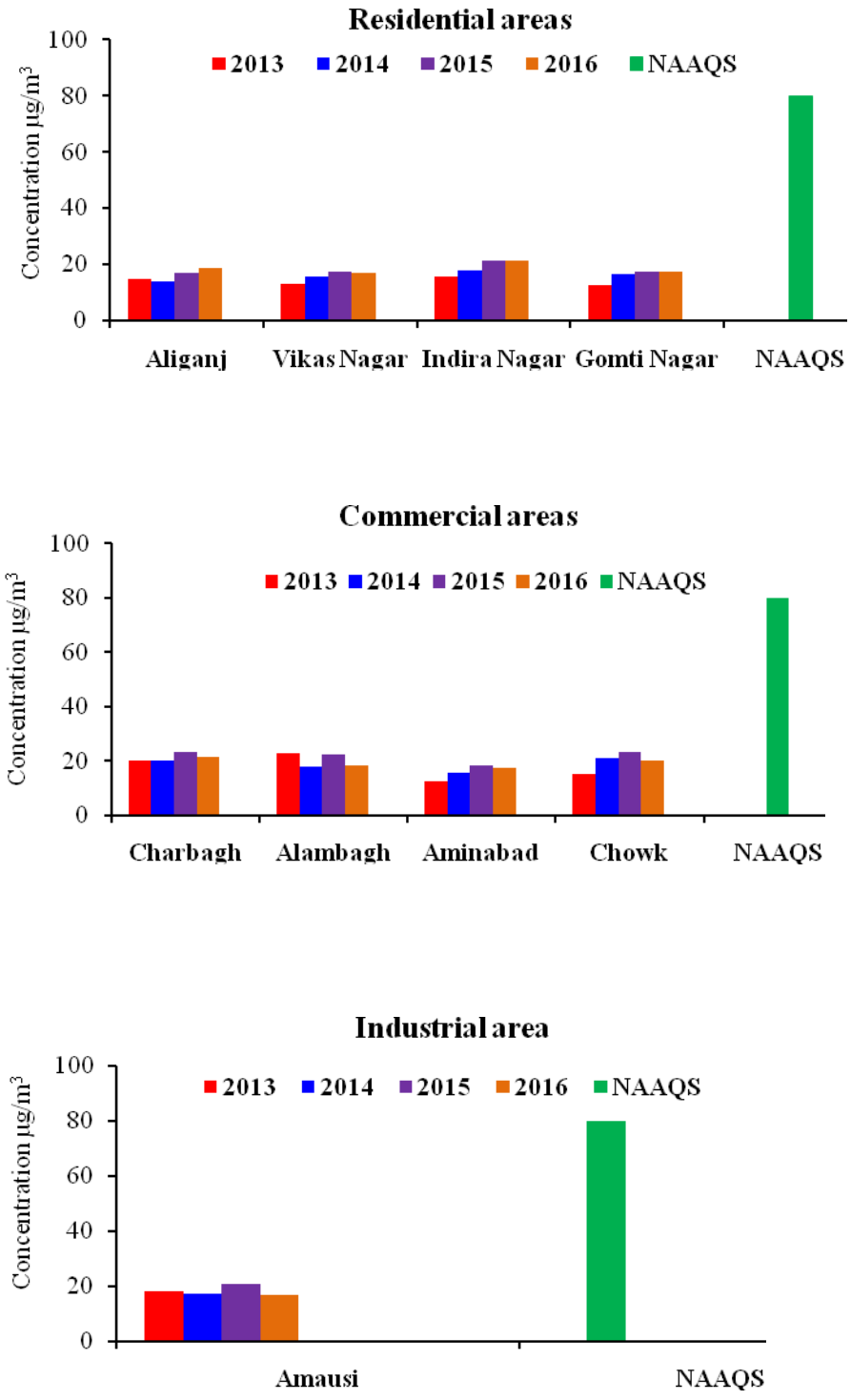


Figure 5: Concentration (µg/m^3) of SO_2 in residential, commercial and industrial areas of Lucknow city during 2013 to 2016 and compared with prescribed standard (NAAQS-2009).

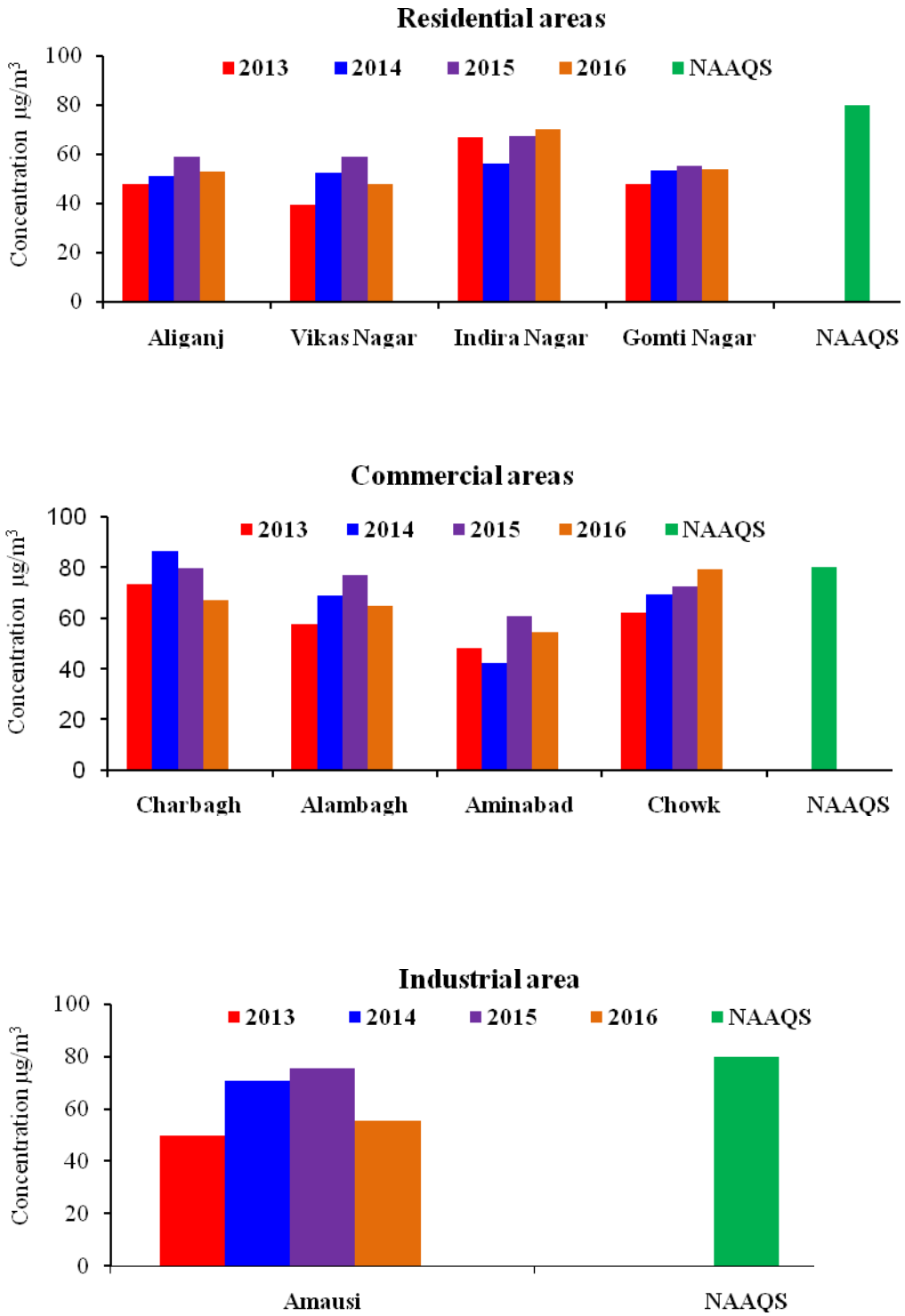


Figure 6: Concentration (µg/m^3) of NO_2 in residential, commercial and industrial areas of Lucknow city during 2013 to 2016 and compared with standard (NAAQS-2009).

1.4.4 Noise Level

Current year's noise data has been compared with the corresponding data of the previous three years and are presented in Figure 7 and 8. The comparative noise level 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 increasing trend over the previous year. In commercial cum traffic areas, noise level was slightly on the higher side at all the locations compared to the previous year except Alambagh. The comparative data are presented in (Figure 7). In industrial area, Amausi the noise level was slightly high than the previous year.

1.4.4.2 Night time noise level

Residential and commercial areas showed slightly higher trend than the last year level except Aliganj and Vikas nagar in residential area and Aminabad in commercial area. The comparative data is presented in (Figure 8). The industrial areas also showed slightly higher level than the previous year but lower than the standard noise level.

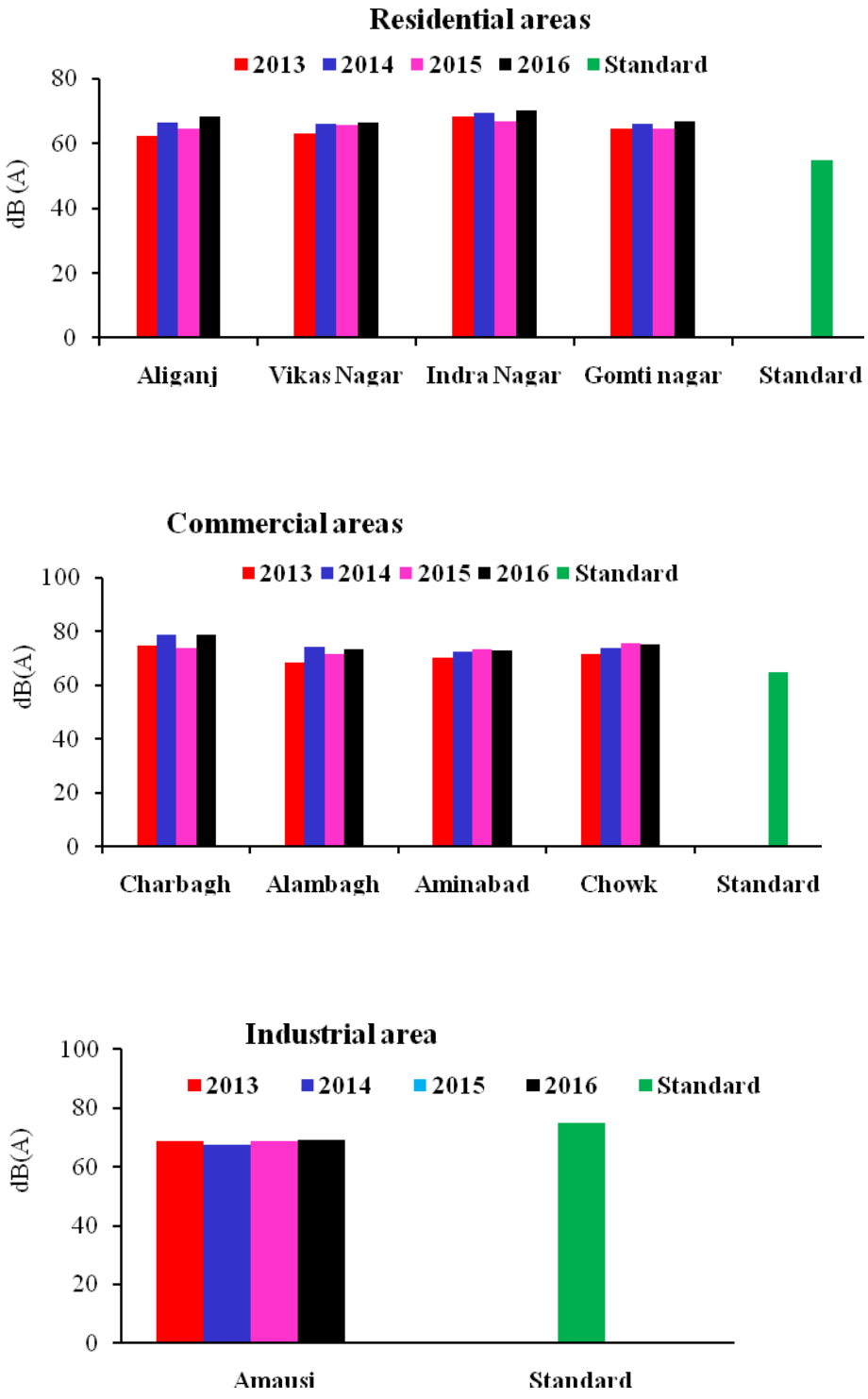


Figure 7: Comparison of day time noise level dB (A) in different areas of Lucknow city (2013-2016).

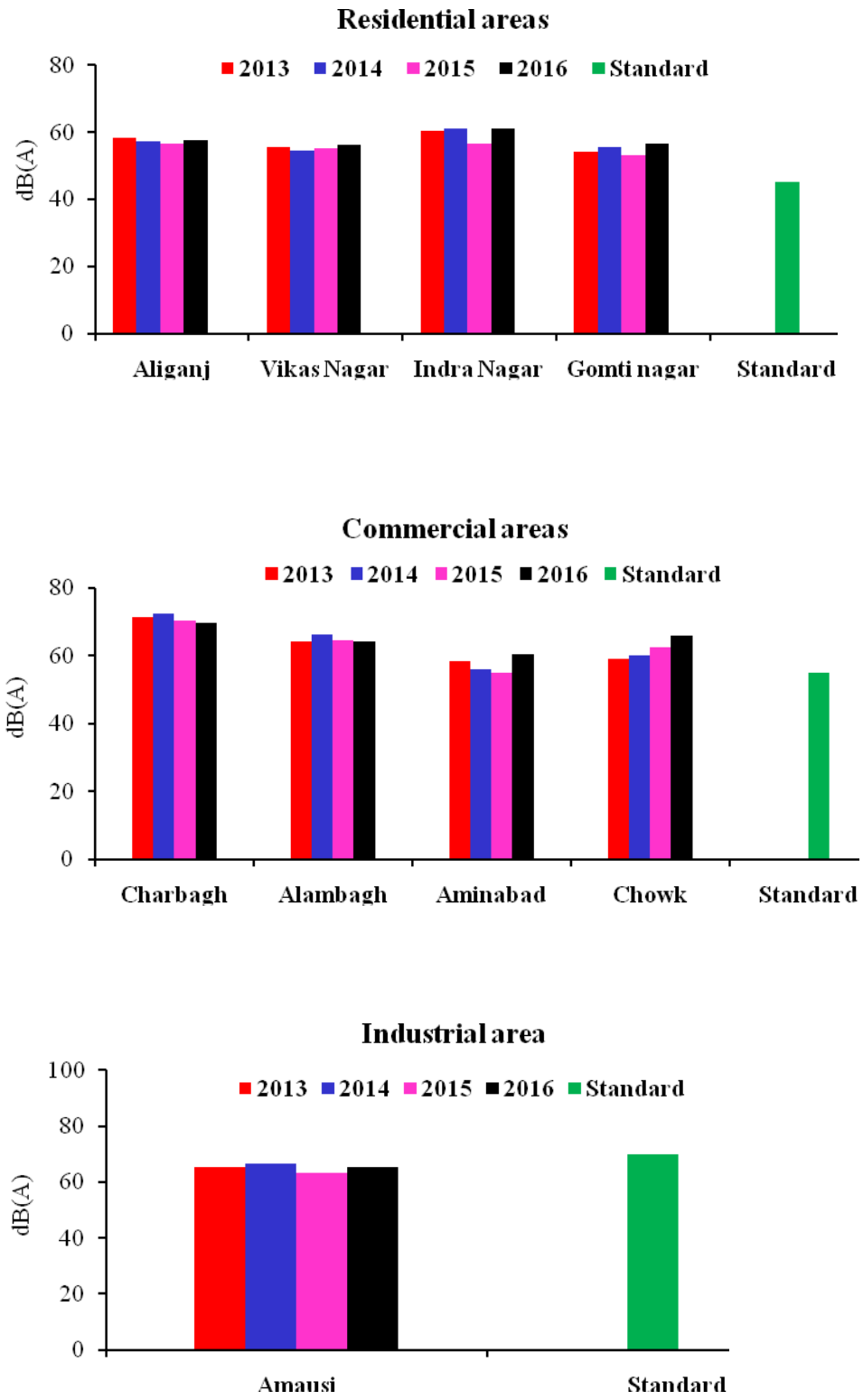


Figure 8: Comparison of night time noise level dB (A) in different areas of Lucknow city (2013-2016).

1.5 HEALTH EFFECTS

At elevated levels, all the pollutants including metals induce adverse effects on human and environmental health. Accumulation of pollutants in the human body through inhalation of air is an important route. The effect of particulate matter depends on the mass and number concentration, shape and size and the composition and concentration of other inorganic and organic pollutants associated with it. Human exposure to particulate air pollution has been identified as a risk factor for human mortality and morbidity. Many countries have revised the limits for PM_{10} as previously defined and prescribed new quantitative standards for $PM_{2.5}$. Nevertheless, PM threshold levels to which exposure does not lead to adverse effects on human health have not yet been clearly identified and hence there is a substantial inter-individual variability in exposure and in the response and it 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. Results presented in this investigation revealed that the higher level of particulate matter (PM_{10}) and especially the finer particles $PM_{2.5}$ at all the monitoring locations have serious health impacts on human being and responsible for several cardiovascular and respiratory diseases such as asthma, bronchitis, reproductive development, increased risk of preterm birth and even mortality and morbidity rate. It is reported that the total daily mortality increased by approximately 1% for every 10 $\mu g/m^3$ increase in PM_{10} concentration.

Metals Ni and Pb can cause cancer through inhalation of fine partiles. In the present study, the concentration of SO_2 and NO_2 were found to be below permissible limit (80 $\mu g/m^3$) of NAAQS-2009 (MoEF 2009), but there are several reports that gaseous pollutants are related with respiratory diseases, reproductive and developmental effect even at low concentration. Vehicular traffic and NO_2 are associated with significantly higher risk of lung cancer.

Noise pollution is now worldwide recognized as a major problem for the quality of life in urban areas. Noise pollution can have adverse effects varying from hearing loss to annoyance. Noise produces both temporary (short period) and permanent hearing loss (long period). Damages caused by noise pollution can range from the bursting of

the eardrum, permanent hearing loss, cardiac and cardiovascular changes, stress fatigue, dizziness, lack of concentration, cause of accident, irritation, inefficiency, nausea, interference with tasks, headaches, insomnia and loss of appetite etc. It also adversely affects future generations and has sociocultural, aesthetic and economic effects.

1.6 CONCLUSIONS

We have monitored air pollutants such as PM_{10}, $PM_{2.5}$, SO_2 and NO_2, particulate trace metals and day/ night noise level for assessment of ambient air quality at nine locations and fine particles in two more locations during post-monsoon (September-October), 2016 and our data revealed the following salient points

- The RSPM (PM_{10}) and fine particle ($PM_{2.5}$) levels at all the monitoring locations of residential, commercial and industrial areas were higher than the NAAQS-2009.
- The concentration of gaseous pollutants, SO_2 was well below the prescribed NAAQS-2009 (80 µg/m^3) at all the locations.
- The concentration of gaseous pollutants, NO_2 was below the prescribed NAAQS-2009 (80 µg/m^3) at all the locations.
- Minimum levels of pollutants were observed during the last week of September and first week of October due intermittent rains during this period. Thus the average values are on the lower side as compared to the average values of the previous year post-monsoon 2015.
- Decreasing trend for PM_{10} was found at all the commercial and industrial areas when compared to the previous year data post-monsoon. The lower value might be due to extended monsoon days till 2nd week of October, 2016.
- The noise levels at all the locations except in industrial area during day and night time showed higher levels than the respective permissible limits.
- Further it is relevant to mention that Diwali day was celebrated on 30th October, 2016 and we also monitored the air quality with the same parameters on pre-Diwali, Diwali and post-Diwali day and found alarmingly higher levels of PM_{10} and $PM_{2.5}$. The short-term adverse changed quality of air due to fireworks have been highlighted in our report released separately and the monitoring has not been included in this report (Reference: annexure-I Diwali report, 2016 is also available in CSIR-IITR, website http://iitrindia.org/pdf/CSIR-IITR%20Diwali%20report-2016.pdf).
- Our pre and post-monsoon results indicate that throughout the year except monsoon season (winter season not covered, which is the worst period with respect to air pollution) particulate matter (PM_{10} and $PM_{2.5}$) levels remain higher than the

permissible limit. The particulate matter is carriers of other pollutants namely trace elements, poly aromatic hydrocarbon (PAHs) etc and among them some are carcinogenic. At present, more than 30 lakh people residing in urban area of Lucknow city is under severe exposure of air pollutants and under threat of health risks especially children, aged people and existing patients.

- Rapid growth of number of vehicles, their technological development and release of invisible tailpipe pollutants emission are serious debatable issues even for the policy makers. Use of different types of fuels namely petrol, diesel and CNG make the environment more complex with respect to air quality and their possible synergistic effects on the human health. Overall, continuous accumulation of different types of pollutants and their exposure to human beings needs emergency attention of the policy makers, researchers and regulatory agencies.
- The latest development of the proposed introduction of metro railway in the city is a positive step in the near future towards reducing the air pollution, through the decrease in vehicular density which clearly indicates proportional association of the severity of the traffic with air pollution. The State Government has a plan to start the Lucknow metro functioning from 2017.
- The present study suggests that it is necessary to monitor the air quality as well as the health effects at regular intervals at the strategic locations in Lucknow. Our post-monsoon monitoring survey might be helpful to focus on the pollution level in Lucknow city and its probable consequences. Our database of air quality since 1997 will help the planners for sustainable development of the Lucknow city.

1.7 RECOMMENDATIONS

- Public transport must be strengthened to minimize use of personal vehicles.
- Improvement in the traffic management and strict implementation of traffic rule.
- Encroachment should be removed for smooth flow of traffic.
- Public awareness programme should be conducted for highlighting harmful effects of vehicular/ air pollution.
- Pressure horns to be removed from all vehicles and avoid use of horn.
- Restore foot path for pedestrians.
- Stop burning municipality waste, biomass, wood, leaves and solid waste.
- Develop green belt area, market place, play grounds especially in new area included in master plan.
- Provision for more electric crematorium in the city.
-

- Regular monitoring of air quality.
- Increase of monitoring station and regular monitoring of air quality.
- Indoor air quality study and systematic collection health status data.
- Regular information of air quality data with minimum and maximum exposure period of the day and permissible limits to be shared with the public.
- An alarm system to be developed with web based application to warn the citizens of the dangers of environmental pollution.

Acknowledgements

We 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 necessary vehicular and oil consumption data. We also express our sincere thanks to Lucknow city for providing necessary facilities at different monitoring locations.

Annexure: I

Assessment of Ambient Air Quality during Pre-Diwali, Diwali and Post-Diwali Festival, October 2016

Assessment of Ambient Air Quality during Pre-Diwali, Diwali and Post-Diwali Festival, October 2016

Diwali 2016 Pollution Survey
Environmental Monitoring Division
CSIR-Indian Institute of Toxicology Research
Vishvigyan Bhawan, 31 Mahatama Gandhi Marg, Lucknow – 226001, UP

CSIR-Indian Institute of Toxicology Research (CSIR-IITR), Lucknow conducted Air Quality survey at seven locations including four residential (Aliganj, Vikas nagar, Indira nagar and Gomti nagar), one office (IITR-Vishvigyan bhavan) and two commercial areas (Aminabad and Chowk) of Lucknow city to assess the impact of fireworks on the environment during the Diwali festival, 2016. Collected results revealed that the respirable particulates during pre-Diwali, Diwali and post-Diwali are well above the National Ambient Air Quality Standards of 60 and 100 $\mu g/m^3$ for $PM_{2.5}$ and PM_{10} respectively.

During the major event on Diwali night October 30th, 2016 the mean level of $PM_{2.5}$ increased from 248.1 to 672.2 $\mu g/m^3$ over the pre-Diwali night and reduced to 308.9 $\mu g/m^3$ during post-Diwali night. Similarly on Diwali night, the level of PM_{10} also increased from 360.1 to 863.8 $\mu g/m^3$ over the pre-Diwali night and reduced to 460.4 $\mu g/m^3$ during post-Diwali night. The bursting of crackers is responsible for increasing trend of particulate levels as other sources such as traffic and industry activities were at the minimal contribution levels during the period on account of Diwali holidays.

On the Diwali night $PM_{2.5}$ increased by 170.9% whereas the increase in PM_{10} over the pre-Diwali night was 139.8%. Further, the higher levels of particulates continued during post-Diwali night by 24.5% and 27.9% for $PM_{2.5}$ and PM_{10} respectively over pre-Diwali night levels (Figure I).

In case of SO_2 and NO_2, the mean levels were found to be within prescribed limits whereas, mean level of SO_2 on the Diwali night increased from 15.1 to 29.7 $\mu g/m^3$ and on post-Diwali mean SO_2 level was 18.3 $\mu g/m^3$, indicate the levels increased 96.7 % and 21.2% on the Diwali night and post-Diwali night respectively over the pre-Diwali night.

The mean level of NO_2 on Diwali night increased from 54.2 to 94.2 $\mu g/m^3$ over the pre-Diwali night. On the post-Diwali night mean of NO_2 was increased from 54.2 to 60.9 $\mu g/m^3$. In term of percentage, NO_2 level increased 73.8 and 12.4 on Diwali night and post-Diwali night respectively over the pre-Diwali night.

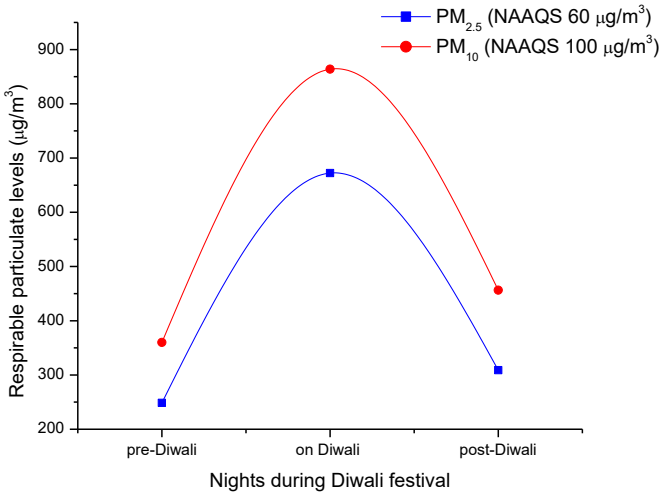


Figure I: Profile of respirable particulates during the night time of Diwali festival.

The meteorological conditions, particularly wind speed and directions play a major role in the transport and dispersion of the pollutants from their source. On Diwali night, which is the beginning of winter, changes in meteorological conditions also contributes to the causes of high pollution levels in the city besides the source of emission. Apparently the wind condition remains calm most of the time especially during cracker bursting and on the other hand it can be stated that weather condition was stable during night hours of the study period.

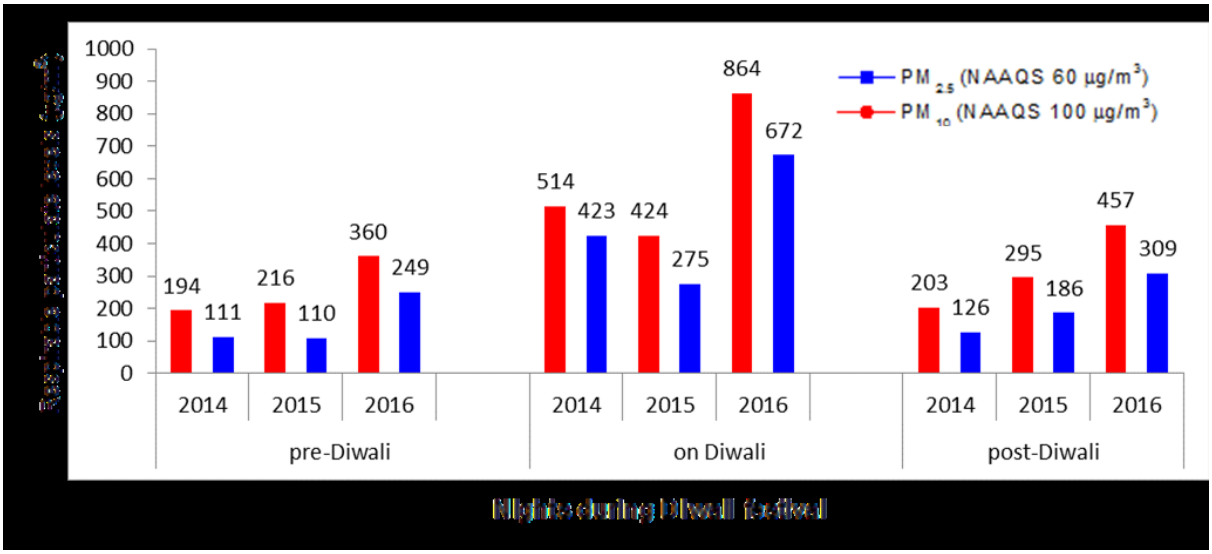


Figure II: Levels of respirable particulates (PM_{10} and $PM_{2.5}$) concentration during 2014, 2015 and 2016 (Diwali festival).

Table I: CSIR-IITR Diwali 2016 pollution survey.

Pollutants/ Locations	pre-Diwali 2016 (October 29th, 2016)		on-Diwali 2016 (October 30th, 2016)		post-Diwali 2016 (October 31st, 2016)	
	Day (6:00 am to 6:00 pm)	Night (6:00 pm to 6:00 am)	Day (6:00 am to 6:00 pm)	Night (6:00 pm to 6:00 am)	Day (6:00 am To 6:00 pm)	Night (6:00 pm to 6:00 am)
PM_{10} ($\mu g/m^3$)						
IITR (Vishvigyan bhavan)	269.7	277.5	226.8	861.5	184.6	423.6
Aminabad	241.2	203.4	311.3	674.4	243.5	415.5
Chowk	463.2	435.0	309.9	967.1	Not run	434.1
Aliganj	274.7	418.1	338.9	886.9	Not run	388.4
Vikas nagar	230.6	424.5	244.5	986.8	244.65	481.2
Indira nagar	245.8	384.7	378.0	881.3	312.2	543.8
Gomti nagar	268.9	377.2	205.9	788.3	236.3	536.4
$PM_{2.5}$ ($\mu g/m^3$)						
IITR(Vishvigyan bhavan)	166.8	317.4	138.0	750.9	129.2	304.4
Aminabad	96.8	188.4	169.1	384.5	83.1	196.8
Chowk	205.5	221.7	330.0	792.6	Not run	232.5
Aliganj	129.7	232.1	70.0	713.4	Not run	260.3
Vikas nagar	170.1	260.3	170.2	769.9	165.8	340.3
Indira nagar	226.8	246.1	341.7	685.7	225.7	453.5
Gomti nagar	145.0	274.1	136.3	608.5	128.2	374.7
SO_2 ($\mu g/m^3$)						
IITR(Vishvigyan bhavan)	11.5	14.7	13.2	28.6	12.3	15.7
Aminabad	13.4	16.9	13.6	21.3	9.4	11.2
Chowk	15.8	19.9	16.1	39.6	Not run	22.2
Aliganj	9.8	13.8	13.5	24.3	Not run	17.8
Vikas nagar	8.9	14.6	10.5	34.6	10.4	20.1
Indira nagar	10.3	15.1	11.8	29.0	11.5	21.4
Gomti nagar	8.3	10.3	12.8	30.6	10.8	19.7
NOx ($\mu g/m^3$)						
IITR(Vishvigyan bhavan)	18.3	77.3	63.4	85.3	30.4	68.5
Aminabad	24.9	34.5	33.2	53.8	26.3	39.2
Chowk	59.9	43.0	75.3	147.8	Not run	98.8
Aliganj	31.3	42.6	71.2	98.1	Not run	56.4
Vikas nagar	21.3	35.8	29.3	89.6	18.7	58.8
Indira nagar	37.4	74.7	69.2	97.9	27.8	53.4
Gomti nagar	47.9	71.5	53.7	86.7	23.8	51.4

Number Concentration of Finer Particles (size range 0.3µm to 2.5 µm)

Real time monitoring of finer particles was carried out at Vikas nagar during pre-Diwali, post-Diwali and on Diwali day 2016. During night hours (especially during fireworks event) the data revealed that finer particles in the size range of 0.3 µm to 2.5 µm and its number concentration significant goes high and the hourly average concentration crossed more than 6 x 10^9 per m^3 and which was recorded less than 3 x 10^9 per m^3 on pre-Diwali day.

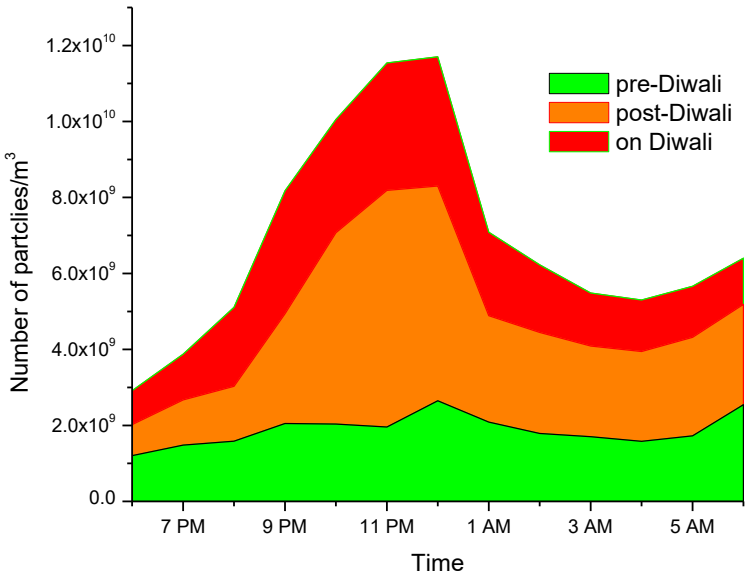


Figure III: Particle number concentration during pre-Diwali, post-Diwali and on Diwali.

Noise Level

Noise level was recorded during pre-Diwali, post-Diwali and on Diwali night to see the impact of bursting of fire cracker at following locations. The monitoring was carried out during 7 pm, to midnight for near about 30 minutes at each location. The maximum level was recorded 92.3 Leq dB(A) at Chowk area and whereas minimum was recorded 77.8 dB(A) at Aminabad on the Diwali night. The recorded value is given in Table II.

Table II: Noise Level on pre-Diwali, Diwali and post-Diwali night.

Locations	**pre-Diwali** (October 29th,2016)	**on-Diwali** (October 30th, 2016)	**post-Diwali** (October 31st, 2016)
	Noise dB(A)		
Aminabad (11:30-12 PM)	ND	77.8	67.7
Chowk (10:30 to 11:30 PM)	70.1	92.3	78.1
Aliganj (9:30 to 10 PM	65.6	78.7	76.5
Vikas nagar (8:15-(PM)	66.3	84.5	69.6
Indira nagar (9:30-10 PM)	68.7	88.8	72.5
Gomti nagar (6:30 -7 PM)	67.6	85.1	73.2

ND= Not done.

The CSIR-IITR mission towards pollution free environment and minimizing/regulating on the use of crackers is an integral part in all its activities/exhibitions and programme amongst the students, family members of staffs, general public and media persons. CSIR-IITR teams also visit schools of the city and surrounding villages to spread the awareness. Air quality results observed during the year clearly indicate that the air quality of the city significantly deteriorated due to fireworks for the short period which can severely affect human health particularly in case of children, senior citizens and people with respiratory issues. Therefore, we discourage the use of fireworks during festivals.