Assessment of Ambient Air Quality of Lucknow City

Post-Monsoon 2017

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)	:	Mr. Tajuddin Ahmed
		Mr. Pradeep Shukla
		Mr. Khalil Ahmed
		Mr. B.M. Pandey
Other Participants (Project Fellows)	:	Ms. Priya Saxena
		Mr. Hamid Kamal
		Mr. Ankur Dixit
		Mr. Mohd Irfan
		Ms. Riddhi Rai

CONTENTS

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** : 28,150,33 as per 2011 Census
- **Projected Population** : 65 lakhs as per Master Plan 2031
- **Climate** : Subtropical climate, cool dry winter (Dec. - Feb.) & summer (Mar - Jun.). Temperature about 45^{0}C in summer to 3^{0}C in winter. Average annual rainfall about 100 cm.
- **Total Vehicular Population in Lucknow city as on 31/03/2017** : 19,78,345
- **Growth of Vehicle over 2015-2016** : 6.1%
- **Total No. of Filling Stations (Petrol/Diesel/CNG)** : 123
- **Consumption of Petrol** : 1,93,345 KL
- **Consumption of Diesel** : 2,30,626 KL
- **Consumption of CNG** : 3,21,34,736 kg
- **Major Source of Pollution** : Automobiles, D. G. sets, Civil Construction activities
- **Parameters Monitored** : PM_{10}, $PM_{2.5}$, Sub fraction of fine particles, SO_2, NO_2, trace metals and noise levels
- **Study Conducted by** : Environmental Monitoring Division CSIR-IITR, Lucknow

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

1.0 SUMMARY

This study was carried out during the month of September-October, 2017 (Diwali period not considered) to investigate the status of air quality by monitoring and assessment of some 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 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 99.5 to 358.4 $\mu g/m^3$ with an average of 196.6 $\mu g/m^3$, whereas 24 hours $PM_{2.5}$ level were found to be in the range 50.5 to 166.4 $\mu g/m^3$ with an average of 101.5 $\mu g/m^3$. The average values of PM_{10} and $PM_{2.5}$, irrespective of the locations were found to be above the permissible limit (PM_{10} =100 and $PM_{2.5}$ = 60 $\mu g/m^3$) prescribed by MoEF. Twenty four hours concentration of SO_2 and NO_2 were found in the range of 6.8 to 20.7 and 20.3 to 91.5 $\mu g/m^3$ with an average concentration of 13.8 and 50.5 $\mu g/m^3$ respectively and all the values were below the permissible limits (80 $\mu g/m^3$). Trace metals Ni and Pb were found to be associated with PM_{10}. Twenty four hours concentration of Ni was found to be in the range of 4.18 to 57.71 with an average of 22.26 ng/m^3. The average Ni concentration was found to be above the permissible limit of annual average (20 ng/m^3). In case of Pb, 24 hours concentration in PM_{10} was found to be in the range of 105.41 to 516.38 with an average of 199.87 ng/m^3 which was within the permissible limit (1000 ng/m^3). Noise levels during day and night time were in the range of 64.8 to74.9 dB(A) and 61.3 to 70.3 dB(A) respectively in residential area which were above the permissible limits (day time 55.0 and night time 45.0 dB(A)). The corresponding values of commercial area day time ranged between 71.0 to 76.0 dB(A) and night time 62.4 to 70.0 dB(A) exceeding the limits (day time 65.0 and night time 55.0 dB(A)). In industrial area recorded day time value, 75.5 db(A) and night time 71.7 dB(A) was slightly higher than limits of 75.0 and 70.0 dB(A) during day and night time respectively.

1.1 INTRODUCTION

Air quality monitoring programmes across the country reveal a constantly declining trend in urban air quality which is in turn responsible for a marked increase in morbidity and mortality rates in our cities. In spite of the changed human mindset and government initiatives like the *Swachch Bharat Abhiyan* alongwith ongoing regulatory efforts, much remains to be done. The fast growing human and vehicular population in urban areas coupled with a boom in the construction and other service oriented industries has led to an unprecedented increase in Urban Air Pollution. As a result of such deteriorations, there is a serious concern prevailing among the health conscious people who are living in metro cities especially in developing countries mainly in South Asia. In the present context, it is a reality that innumerable losses in all aspects of the environment including climate change are simply not measurable. RSPM (Respirable Suspended Particulate Matter) or PM_{10} alongwith $PM_{2.5}$ or Fine Particulate Matter can be identified to be the main culprit behind worsening of air quality in most of the North Indian cities. Scientific research and evaluation is going on throughout the world regarding air pollution, its source and effects especially on human health and its outcome. The matter is serious enough and is gradually becoming one of the priority concerns of the government as well as a challenge for the policy makers, regulatory bodies, administrators, workers and scientific community.

The post monsoon season witnesses a number of changes in ambient air quality such as the dipping of night time air temperatures resulting in the formation of an inversion layer that traps pollutants near the ground level. India being primarily an agrarian economy, the months of September and October are marked by preparations for the Rabi or winter season crop. Such preparations often include burning of agriculture residue from the previous cropping season producing a huge amount of smoke, dust and particulate matter which reaches adjoining cities. This is also the time when the Diwali festival or the “festival of lights” is celebrated with huge pomp and show in the entire country. Burning of fire crackers during this festival also adds to the already deteriorating air quality. Therefore, this season observes high pollutant concentrations in most of the North Indian cities.

The sources of air pollutants in urban areas namely tail pipe emission from vehicles, generator-sets, industrial operation, burning of solid waste, urban kitchen waste, re-suspension of soil, etc. generate a number of pollutants in the air such as Particulate Matter (PMs), Sulphur dioxide (SO_2), Nitrogen dioxide (NO_2), and other inorganic (trace elements) and organic pollutants (PAHs), etc. Major sources of these pollutants are due to burning of fossil fuel [petrol, diesel, compressed natural gas (CNG), Liquid Petroleum gas (LPG), coal, etc.]. Due to change of technologies and change of fuel consumption patterns, the composition ratio of each pollutant is also changing over time. The changing scenario demands continuous assessment of air quality as well as its health effects.

When a pollutant is released in the ambient environment from its source it interacts with other pollutants and micrometeorological factors which may enhance its complexation in nature and make it more harmful to human health. So it is necessary to identify the pollutants, their sources, transformation as well as fate of each pollutant and subsequently their impact on environment including living beings.

In view of the above facts, it is the need of the hour to look into the air quality of our city Lucknow, the capital of Uttar Pradesh which 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 19,78,345 as on 31.03.2017 which is 6.1% higher over 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 31.03.2017 are given in Table 2. In Lucknow city there are 123 filling stations for petrol, diesel and CNG operated by different oil companies (Table 3).

As per Oil Marketing Company [Indian Oil Corporation (IOC), Bharat Petroleum Corporation Limited (BPCL), Hindustan Petroleum Corporation (HPCL)] the

consumption/ sale of petrol and diesel was 1,93,345 and 2,30,626 KL as on 31-03-2017. It is observed that petroleum sale has increased by 11.36% whereas sale of diesel has increased by 26.38% (Table 4). In Lucknow there are six CNG filling stations and consumption of CNG during last year was approximately 3,21,34,736 kg (2016-17) which was 6.24% higher than the previous year (2015-16) (Green Gas Limited, Lucknow). Distribution and number of CNG vehicles in Lucknow is summarized in Table 5. Considering the above, assessment of ambient air quality of Lucknow city was carried out at 9 locations during post monsoon (September-October), 2017 with respect to PM_{10}, $PM_{2.5}$, sub fraction of fine particles ($PM_{1.0}$, $PM_{0.56}$, $PM_{0.32}$, $PM_{0.18}$, $PM_{0.1}$), SO_2, NO_2 and Noise level with the following aims and objectives:

- *To assess the ambient air quality with respect to PM_{10}, $PM_{2.5}$, sub fraction of fine particles ($PM_{1.0}$, $PM_{0.56}$, $PM_{0.32}$, $PM_{0.18}$, $PM_{0.1}$), SO_2, NO_2, Trace metals and Noise level.*
- *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
Comparison of Vehicular Population in Lucknow

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

Source: RTO, Lucknow

Table 2
Details of Lucknow City Bus Service, 2017

S. No	Route No.	To and Fro	No. of Buses	Frequency
1	11	BBD – Chinhat - Gomti Nagar - Alambagh 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	12	15 minute interval
2	12	Barabanki - Safedabad Crossing - Ramswarup College - Tewariganj - BBD - Chinhat - HAL Nishatganj - Sikindrabad - KKC College - Charbagh	24	15 minute interval
3	12 D	Charbagh – KKC- Vikas Deep-Husainganj-Burlington—Bapu Bhawan-GPO-Shakti Bhawan- Sikanderbagh- Dainik Jagaran-Trikonia Park-FUN Republic-Lohia park-BB D Academy- CMS- Vishal Khand—PS Gomtinagar-Chinhat More-matiaretoraha-mati-DEVA.	05	45 minute interval
4	23	Integral University-Gudamba-Vikasnagar– Nishatganj -Sikandrabad - Hussainganj - Alambagh - Rajnikhand Gudamba - Badshanagar - Avadh Hospital	17	10 minute interval
5	31	IM Sector Q-Beligaradh-PNT-Purania-Kapoorthala-ChanniLaL - Mahanagar -Gole market - Badhshanagar - Nishatganj - Hussainganj - Charbagh - Alambagh Chouraha.	2	60 minute interval
6	31 A	Charbagh - Hussainganj - Sikandrabagh - Gokhale Marg - Nishatganj - Badshahnagar - Gole market - Channilal-Kapoorthala-Purania-Engineering College - Sewa Hospital - Bakshi Ka Talab	1	120 minute interval
7	33	Engineering College - Charbagh - Alambagh - Scooter India	12	20 minute interval
8	33 C	Bhitoli - CDRI Chowraha - Jankipuram - Purania - Mahanagar - Badshahnagar - Nishatganj - Hussainganj - Charbagh - Alambagh Cowraha.	4	20 minute interval
9	33 S	Bhitoli Chowraha - Engineering College – Kapoorthala - Badshahnagar – Nishatganj – Hussainganj – Charbagh – Alambagh -Bhudeswar Chowraha - Dr. Sukuntala Mishra University.	1	180 minute interval
10	33 PGI	SGPGI - Telibagh - Alambagh - Charganj - Hussainganj - GPO - Mahanagar - Engineering College.	8	12 minute interval
11	33 LU	Parivartan Chowk - IT Chowraha - Vivekananda Hospital -Kapoorthala - Engineering College - New Campus Lucknow University	2	45 minute interval
12	43 H	New High Court-Polytechnic-Munshiphulia-Khuramnagar Chowraha-Jagrani Chowraha-Teriphulia-Dubagga Chowraha	04	45 minute interval
13	45	Virajkhand - Gomti Nagar - Charbagh - Alambagh - Paasi Kila - Aurangabad - Shahid path	14	15 minute interval
14	48 B	Kesarbagh-Bapubhawan-Chief minister house-Lohia Chowraha-Polytechnic-Aahimou-Khurdahi Bazar-Gosainganj-Haidergarh/	02	120 minute interval
15	500 S	Raja Suchana Aayog-Kamta Chowraha-Aahimau-Uttaria-PGI-Mohanlalganj-Sisandhi	01	120 minute interval
		Total	107	

Source: Lucknow City Transport Services Limited.

Table 3
Fuel Outlets in Lucknow City

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

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

Table 4
Consumption of Fuel in Lucknow

S. No.	Agency	Petrol in kl			High Speed Diesel in kl			CNG in kg		
		Apr. 15 to Mar. 16	Apr. 16 to Mar. 17	% Cha-nge	Apr. 15 to Mar. 16	Apr. 16 to Mar. 17	% Cha-nge	Apr. 15 to Mar. 16	Apr. 16 to Mar. 17	% Cha-nge
1	IOC	90507	103065	13.87	86101	91101	5.81	--	--	--
2	BPCL	50570	54630	8.03	54990	55655	1.20	---	--	--
3	HPCL	32540	35650	9.56	41390	83870	102.63	---	--	--
4	Green Gas	--	--	--	--	--	--	30246000	32134736	6.24
Total		**173617**	**193345**	**11.36**	**182481**	**230626**	**26.38**	**30246000**	**32134736**	**6.24**

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

Table 5
Distribution of CNG vehicles

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

Source: RTO, Lucknow

1.2 MONITORING LOCATIONS AND METHODOLOGY

Nine air quality monitoring locations representing different activities/areas i.e., four in residential, four in commercial cum traffic and one industrial area were selected for the study as summarized in Table 6 (brief description of each location is given in our earlier reports (Pre and Post monsoon, 2010) and parameters along with methodology is given in Table 7.

Table 6
Monitoring Locations

S. No.	Locations	Activities
1.	Aliganj	Residential
2.	Vikas Nagar	Residential
3.	Indira Nagar	Residential
4.	Gomti Nagar	Residential
5.	Charbagh	Commercial cum traffic
6.	Alambagh	Commercial cum traffic
7.	Aminabad	Commercial cum traffic
8.	Chowk (King George's Medical University campus)	Commercial (sensitive zone)
9.	Amausi	Industrial

Table 7
Parameters and Methodology for Air Quality Monitoring

S. No.	Parameters	Time weighted average	Methods of Measurement
1.	Particulate Matter (PM_{10})	24 hours	Gravimetric
2.	Fine Particulate ($PM_{2.5}$)	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 and As)	24 hours	AAS/AFS method after sampling on EPM 2000
6.	Noise Level	1 hour	The measurement of noise level was carried out during the day (6 AM to 10 PM) and night time (10 PM to 6 AM) by Noise level Meter

1.3 RESULTS

The detailed results of air quality monitoring are presented in Table 8 and Fig.1.

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

In residential areas (Aliganj, Vikas Nagar, Indira Nagar and Gomti Nagar), the 24 hours average concentrations of PM_{10} were in the range of 169.3 to 212.3 $\mu g/m^3$ with an average of 192.0 $\mu g/m^3$. In commercial areas (Charbagh, Alambagh, Aminabad and Chowk) the average concentrations of PM_{10} were in the range of 187.6 to 211.4 $\mu g/m^3$ with an average of 199.6 $\mu g/m^3$ respectively. In industrial area (Amausi), the average concentration of PM_{10} was 203.1$\mu g/m^3$.

Maximum 24 hours mean concentration of PM_{10} was observed in Indira Nagar (212.3 $\mu g/m^3$) in residential area and Charbagh (211.4 $\mu g/m^3$) in commercial area. Overall, at all the locations, mean values of PM_{10} were above the prescribed National Ambient Air Quality Standard (NAAQS) of 100 $\mu g/m^3$ for industrial, residential, rural and other areas.

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 89.9 to 103.1 $\mu g/m^3$ with an average of 96.1 $\mu g/m^3$. In commercial areas (Charbagh, Alambagh, Aminabad and Chowk) the average concentrations of $PM_{2.5}$ were in the range of 92.3 to 127.6 $\mu g/m^3$ with an average of 108.7 $\mu g/m^3$ respectively. In industrial area (Amausi), the average concentrations of $PM_{2.5}$ were 94.4 $\mu g/m^3$.

The maximum 24 hours mean concentration of $PM_{2.5}$ was observed in Indira Nagar (103.1 $\mu g/m^3$) in residential area and Charbagh (127.6 $\mu g/m^3$) in commercial area. Over all at all the locations mean values of $PM_{2.5}$ were above the prescribed National Ambient Air Quality Standard (NAAQS) of 60 $\mu g/m^3$ for industrial, residential, rural and other area.

1.3.3 Sub Fraction of Fine Particles ($PM_{1.0}$, $PM_{0.56}$, $PM_{0.32}$, $PM_{0.18}$, $PM_{0.1}$)

The monitoring of sub-fractions of fine particles was conducted during the month of October 2017 at two locations i.e city commercial area (CSIR-IITR, Main Campus) and in rural area (CSIR-IITR, Gheru Campus) as reported in Table 9 and Fig.2. The

sub-fractions of fine particles clearly indicated that mass of particulate matter decreased with the size. Total mass concentrations of all five sub-fractions of fine particles were ranged between 66.10 μg/m^3 to 93.91 μg/m^3 (24 hr mean) with an average of 79.90 μg/m^3 in commercial area of Lucknow city, whereas in the rural area value of Ultra Fine Particles ranged from 41.40 to 53.85 μg/m^3 (24 hr mean) with an average of 48.27 μg/m^3 (Table 9). Total mass concentration of particulate matter in various five sub-fractions ($PM_{1.0}$, $PM_{0.56}$, $PM_{0.32}$, $PM_{0.18}$ and $PM_{0.1}$) was higher in commercial area of Lucknow city as compared to rural/village area. For these sub-fraction particles, no International and National guideline is available at this point of time.

1.3.4 Sulphur dioxide (SO_2)

In residential area (Aliganj, Vikas Nagar, Indira Nagar and Gomti Nagar) the mean levels of SO_2 were in the range of 12.8 to 14.6 μg/m^3 with an average of 13.0 μg/m^3. In commercial area (Charbagh, Alambagh, Aminabad and Chowk) the average concentrations of SO_2 were in the range of 11.5 to 18.6 μg/m^3 with an average of 14.2 μg/m^3. In industrial area (Amausi) the average concentration of SO_2 was 14.7 μg/m^3. All the values of SO_2 were well below the prescribed NAAQS of 80 μg/m^3 for all the locations.

1.3.5 Nitrogen dioxides (NO_2)

In residential areas (Aliganj, Vikas Nagar, Indira Nagar and Gomti Nagar) the 24 hours average concentrations of NO_2 were found in the range of 38.2 to 58.9 μg/m^3 with an average of 46.7 μg/m^3. In commercial areas (Charbagh, Alambagh, Aminabad and Chowk) the average concentrations of NO_2 were found in the range of 40.9 to 71.1 μg/m^3 with an average of 56.6 μg/m^3. In industrial areas (Amausi) the average concentration was 41.3 μg/m^3. All the values of NO_2 were within the prescribed NAAQS of 80 μg/m^3 for all the monitoring locations except one commercial location (Charbagh).

Table 8

Concentration (µg/m^3) of PM_{10}, $PM_{2.5}$, SO_2 and NO_2 during Post Monsoon, 2017

	PM_{10} (RSPM)			$PM_{2.5}$			SO_2			NO_2		
Residential												
	Min.	**Max.**	**Avg.**	**Min.**	**Max.**	**Avg.**	**Min.**	**Max.**	**Avg.**	**Min.**	**Max.**	**Avg.**
Aliganj	115.6	267.5	**207.3**	50.5	129.6	**97.7**	6.8	17.9	**12.8**	30	54.5	**44.0**
Vikas Nagar	124.4	245.3	**179.2**	70.0	138.1	**93.8**	8.3	17.6	**13.0**	20.3	55.4	**38.2**
Indira Nagar	99.5	283.1	**212.3**	56.4	158.6	**103.1**	10.3	19.2	**14.6**	31.0	72.3	**58.9**
Gomti Nagar	127.4	223.4	**169.3**	63.7	125.3	**89.9**	6.0	16.0	**11.8**	29.2	58.5	**46.0**
Commercial												
Charbagh	166.0	274.2	**211.4**	105.5	166.4	**127.6**	14.0	20.7	**18.6**	38.4	89.7	**71.1**
Alambagh	123.3	278.5	**195.3**	62.6	134.0	**101.4**	8.8	19.6	**14.2**	33.8	54.3	**46.3**
Aminabad	146.5	358.4	**203.9**	98.7	132.9	**113.4**	8.2	17.2	**12.7**	38.7	91.5	**68.1**
Chowk	137.7	256.9	**187.6**	66.6	115.4	**92.3**	9.2	14.8	**11.5**	28.7	52.6	**40.9**
Industrial												
Amausi	134.5	267.8	**203.1**	59.2	123.7	**94.4**	9.6	19.2	**14.7**	25.6	71.0	**41.3**
NAAQS	**100**			**60**			**80**			**80**		
WHO Guidelines	**50**			**25**			**20***			**40***		

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

Table 9

Minimum, maximum and average levels of particulate matter in fine and ultrafine sub-fractions (24 h mean) during Post- Monsoon 2017

	City Commercial Area			Village/Rural Area		
	Min	Max	Avg.	Min	Max	Avg.
Fine Particles (Sub-fractions) (µg/m^3 24 h mean)						
$PM_{1.0}$ (≤1µm)	19.80	26.53	22.55	8.69	14.63	11.77
$PM_{0.56}$ (≤0.56µm)	15.29	24.90	20.03	10.53	14.20	12.72
$PM_{0.32}$ (≤0.32µm)	12.39	18.27	15.65	9.63	10.71	10.35
$PM_{0.18}$ (≤0.18µm)	10.52	14.11	12.58	7.98	8.33	8.22
$PM_{0.1}$ (≤0.100nm)	8.10	10.10	9.10	4.57	5.98	5.22
Total (fine)	**66.10**	**93.91**	**79.90**	**41.40**	**53.85**	**48.27**

N=3; Instrument used**:** MOUDI Cascade Impactor, USA

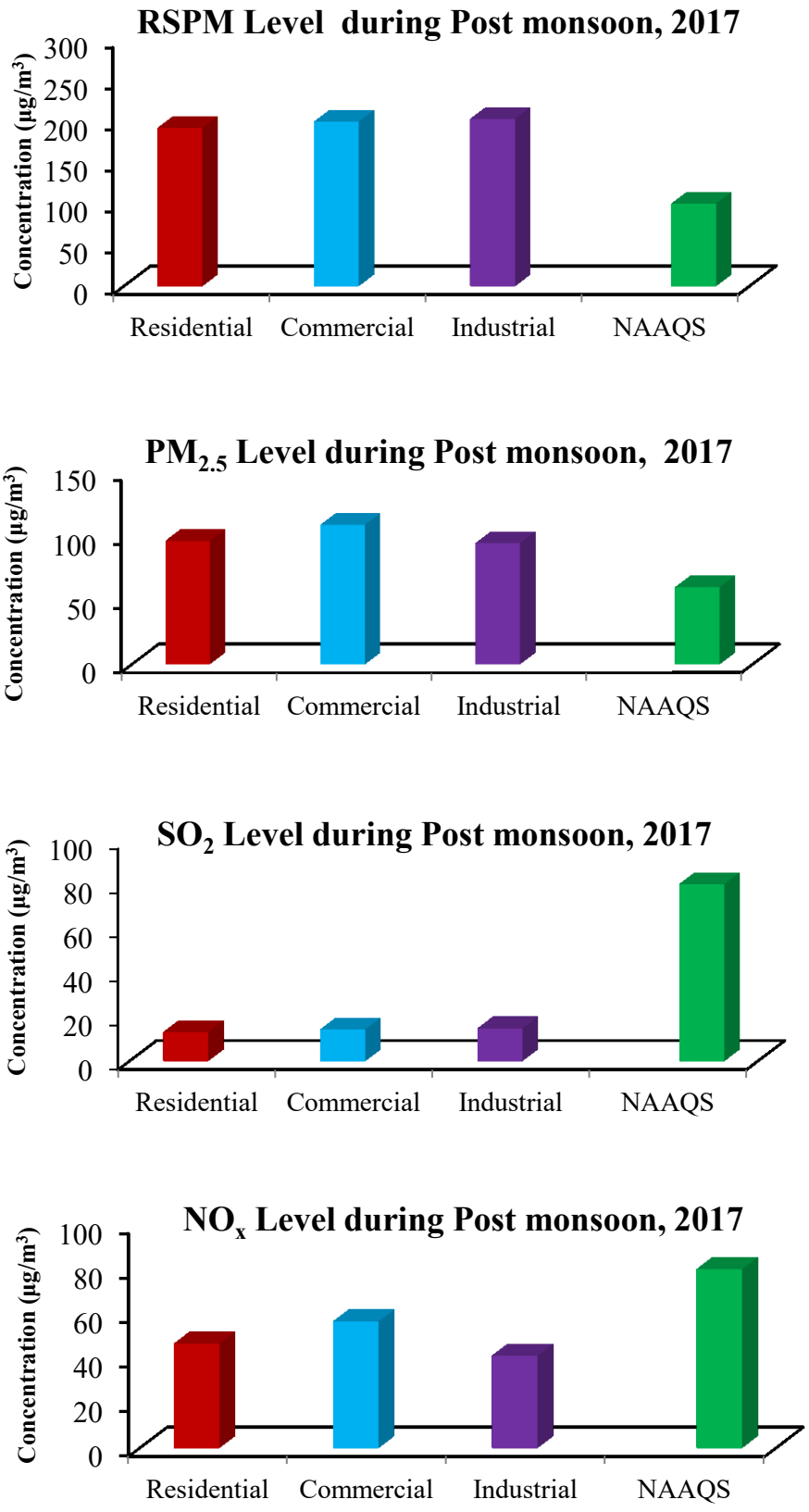

Figure 1: Concentration (µg/m^3) of PM_{10}, $PM_{2.5}$, SO_2 and NO_2 in different areas of Lucknow city during Post monsoon season (2017) and their comparison with prescribed National Ambient Air Quality Standard (NAAQS)

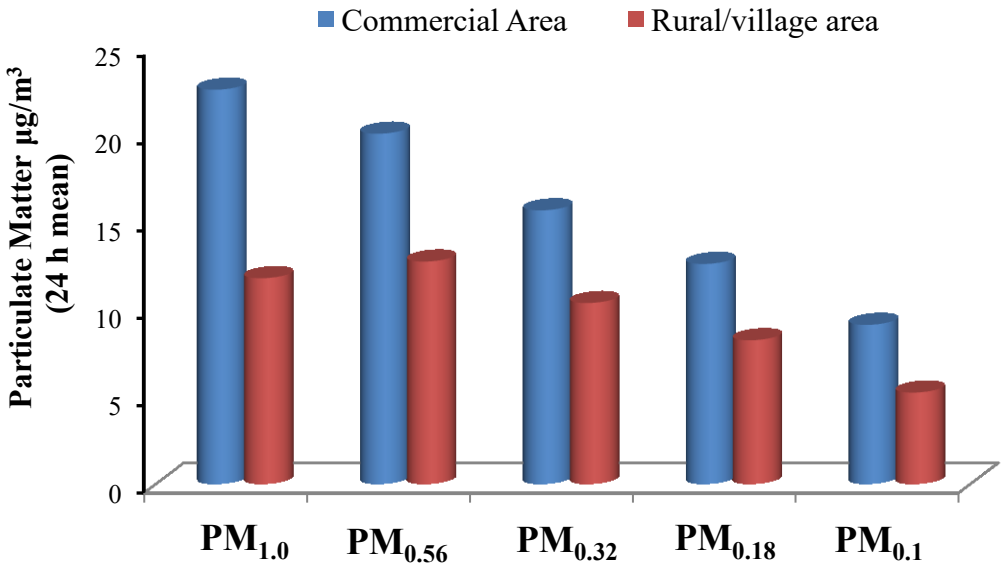

Figure 2: Post- Monsoon levels (Average) of particulate matter in fine particle sub-fractions

1.3.6 Trace Metals in Ambient Air (RSPM or PM_{10} and $PM_{2.5}$)

Trace metals (Ni and Pb) were estimated in ambient air which are associated with PM_{10} at 9 monitoring locations. The results are present in Table 10. Twenty four hours mean concentration of metals in PM_{10} was found to be Ni = 22.26, (4.18- 57.71) ng/m^3 and Pb = 199.87 (105.41-516.38) ng/m^3 .

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

S. No.	Location	Lead (Pb)	Nickel (Ni)
1	Aliganj	216.40	4.18
2	Vikas Nagar	108.21	17.82
3	Indira Nagar	119.14	16.66
4	Gomti Nagar	192.48	22.42
5	Charbagh	233.00	57.71
6	Alambagh	188.23	7.95
7	Aminabad	105.41	8.08
8	Chowk	516.38	13.27
9	Amausi	119.64	52.26
	NAAQS	**1000.0***	**20****

N= 1, NAAQS **Ni =Annual Average; *Pb =24 hrs Average

1.3.7 Noise Level

The monitoring data recorded during the post monsoon period is presented in Table 11.

In residential areas, the day and night time noise levels were recorded between 64.8 to 74.9 and 61.3 to 70.5 dB(A) respectively. All the values were higher than the prescribed limit of 55 and 45 dB (A) for day and night time respectively.

In commercial and heavy traffic area, the day and night time noise level were recorded between 71.0 to 76.6 and 62.4 to 70.0 dB(A) respectively. Noise level at all the commercial sites during day and night time were found above the prescribed limit of 65 and 55 dB (A) respectively.

In industrial area Amausi, the day and night time noise levels were recorded 75.7 and 71.7 dB (A) respectively. Noise levels at the industrial location in the day and night time was found above the prescribed limit of 75.0 and 70.0 dB(A) respectively.

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

Sl. No.	Area	Location	Noise level dB(A)	
			Day	Night
1	**Residential**	Aliganj	74.9	67.9
		Vikas Nagar	64.8	61.3
		Indira Nagar	67.8	70.5
		Gomti Nagar	73.2	70.3
		Standard	**55.0**	**45.0**
2	**Commercial**	Charbagh	76.6	70.0
		Alambagh	71.0	66.0
		Aminabad	76.3	62.5
		Chowk	75.2	62.4
		Standard	**65.0**	**55.0**
3	**Industrial**	Amausi	75.5	71.7
		Standard	**75.0**	**70.0**

1.4 TRENDS OF AMBIENT AIR QUALITY IN LUCKNOW CITY

The observed PM_{10}, $PM_{2.5}$, SO_2 and NO_2 values from the last three years' data have been compared to find out the prevailing trend of air pollution in Lucknow city (Fig.3-6). 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, higher values were found as compared to the previous year except Indira Nagar. Among the commercial areas, PM_{10} values were also found to be higher than the previous year except Chowk and an industrial area showed lower value over the last year. All the values were found to be higher than NAAQS (Fig. 3).

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

In all the locations in residential areas, higher values were found compared to the previous year except for Indira Nagar where values showed a dip compared to the previous year. Among the commercial areas, $PM_{2.5}$ values were found to be higher than the previous year except Chowk and an industrial area showed lower value over the last year. All the values are higher than NAAQS (Fig.4).

1.4.3 Sulphur dioxide (SO_2)

Lower concentration was found compared to the previous year at all the residential commercial and industrial areas. All the values were found to be lower than the NAAQS (Fig.5).

1.4.4 Nitrogen dioxide (NO_2)

The level of NO_2 during post monsoon since 2014 is presented in Fig. 4. All the residential areas showed lower values than the previous year. In commercial and industrial areas all the values showed lower values except Aminabad and Charbagh in commercial area. All the values of the present study were found to be lower than the NAAQS (Fig.6).

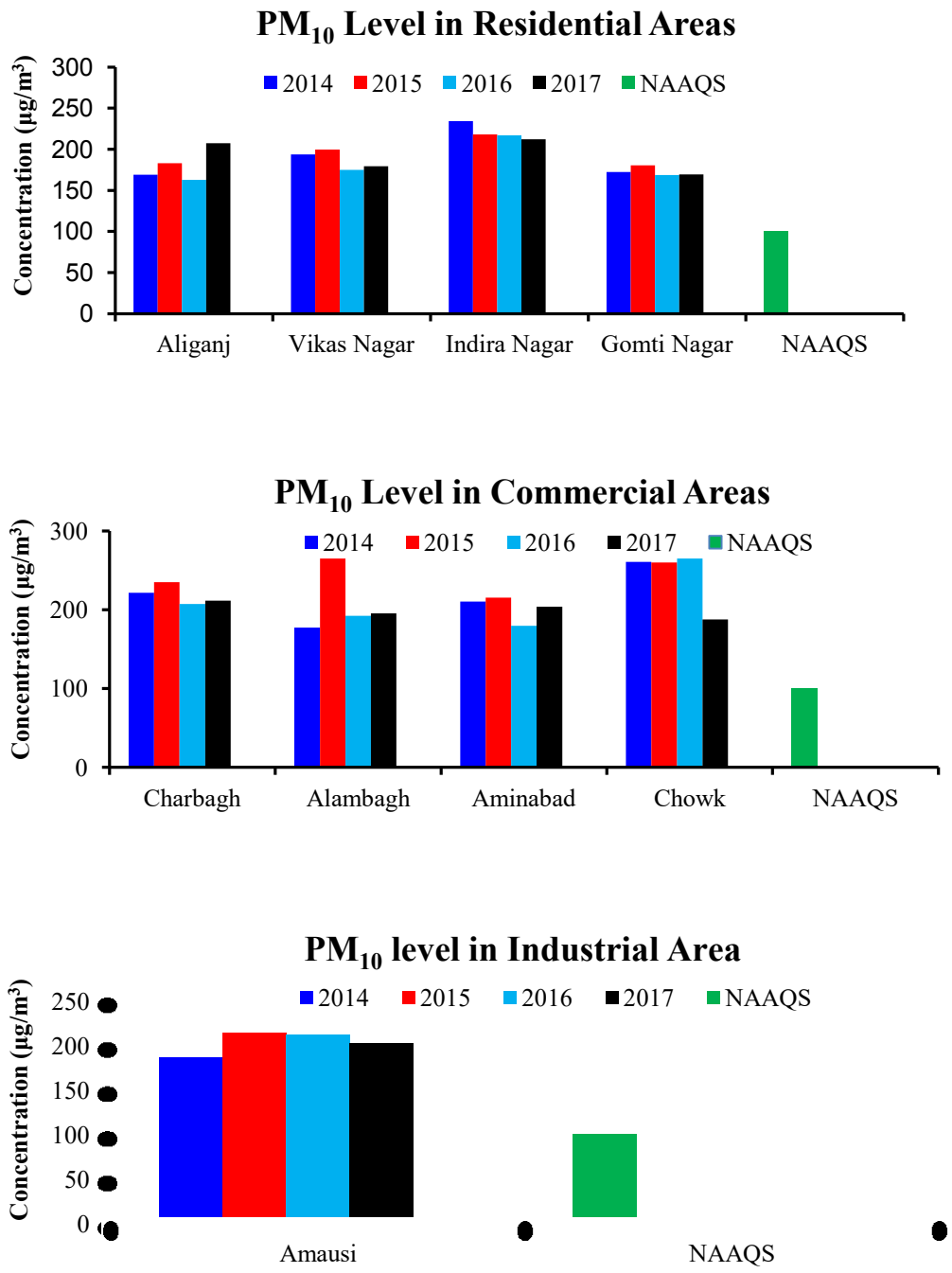

Figure 3: Concentration (µg/m^3) of PM_{10} (RSPM) in Residential, Commercial and Industrial areas of Lucknow city during 2014 to 2017 and comparison with prescribed National Ambient Air Quality Standard (NAAQS)

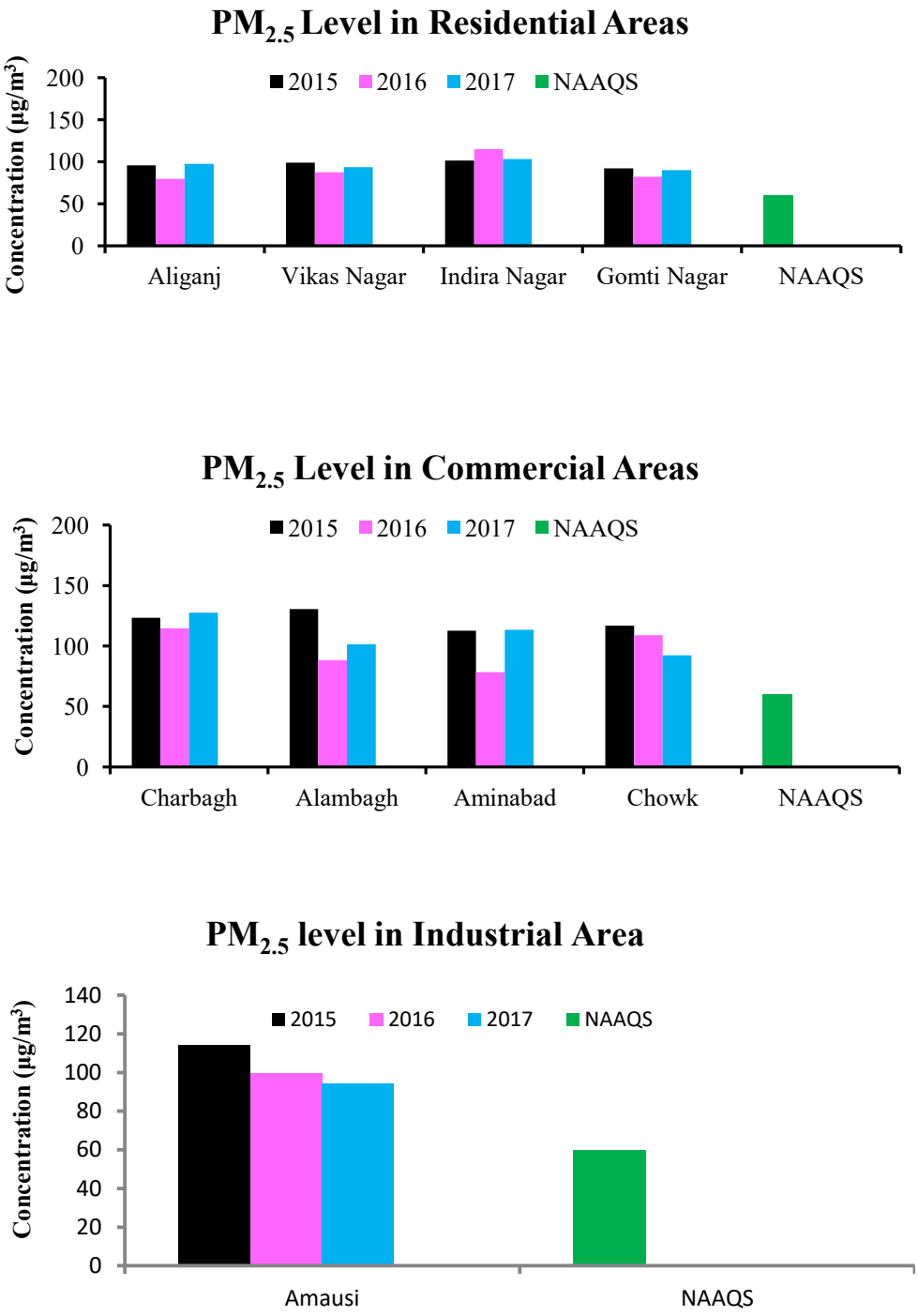

Figure 4: Concentration (µg/m^3) of $PM_{2.5}$ in Residential, Commercial and Industrial areas of Lucknow city during 2014 to 2017 and comparison with prescribed National Ambient Air Quality Standard (NAAQS)

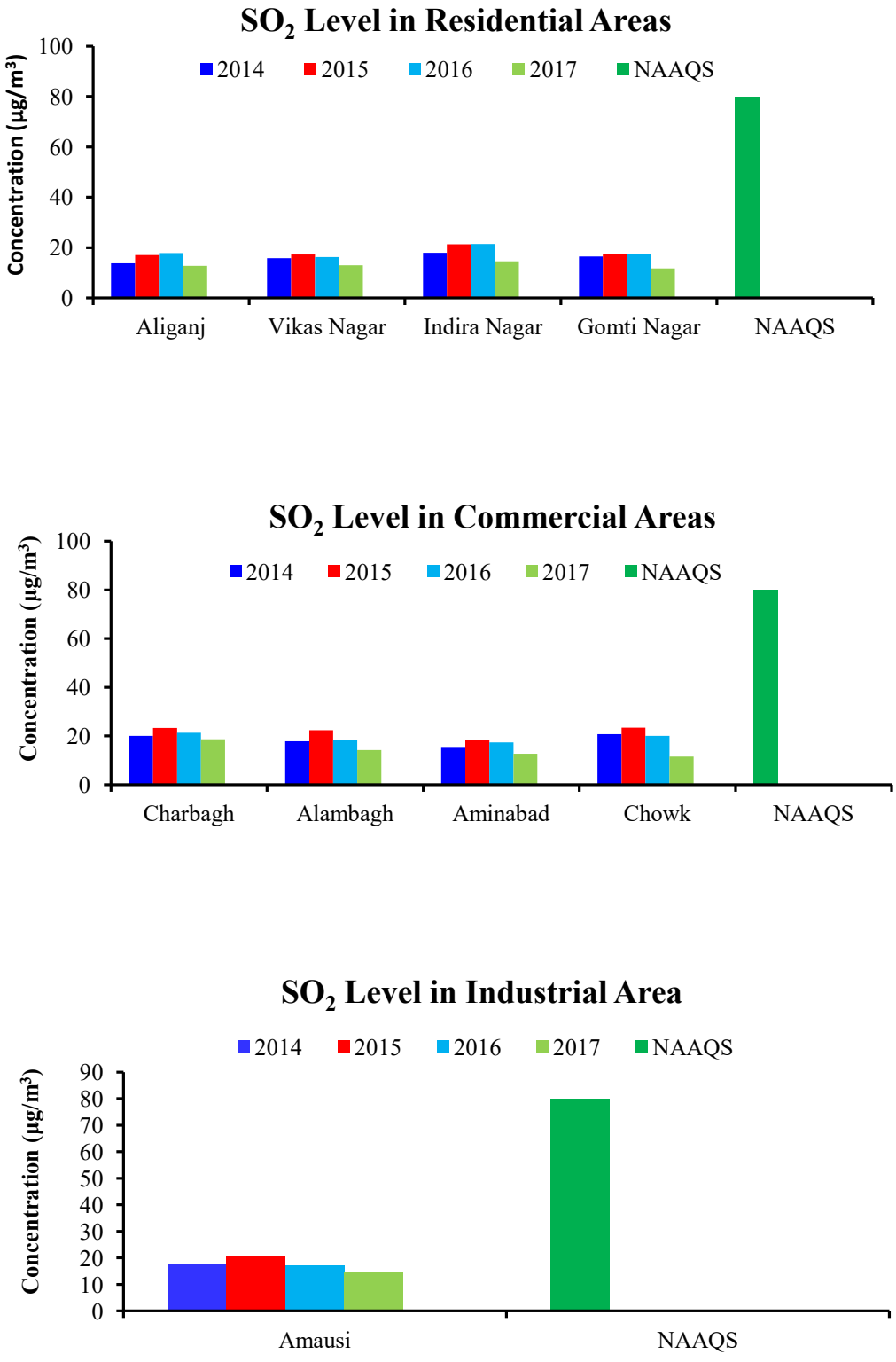

Figure 5: Concentration (µg/m^3) of SO_2 in Residential, Commercial and Industrial areas of Lucknow city during 2014 to 2017 and comparison with prescribed National Ambient Air Quality Standard (NAAQS)

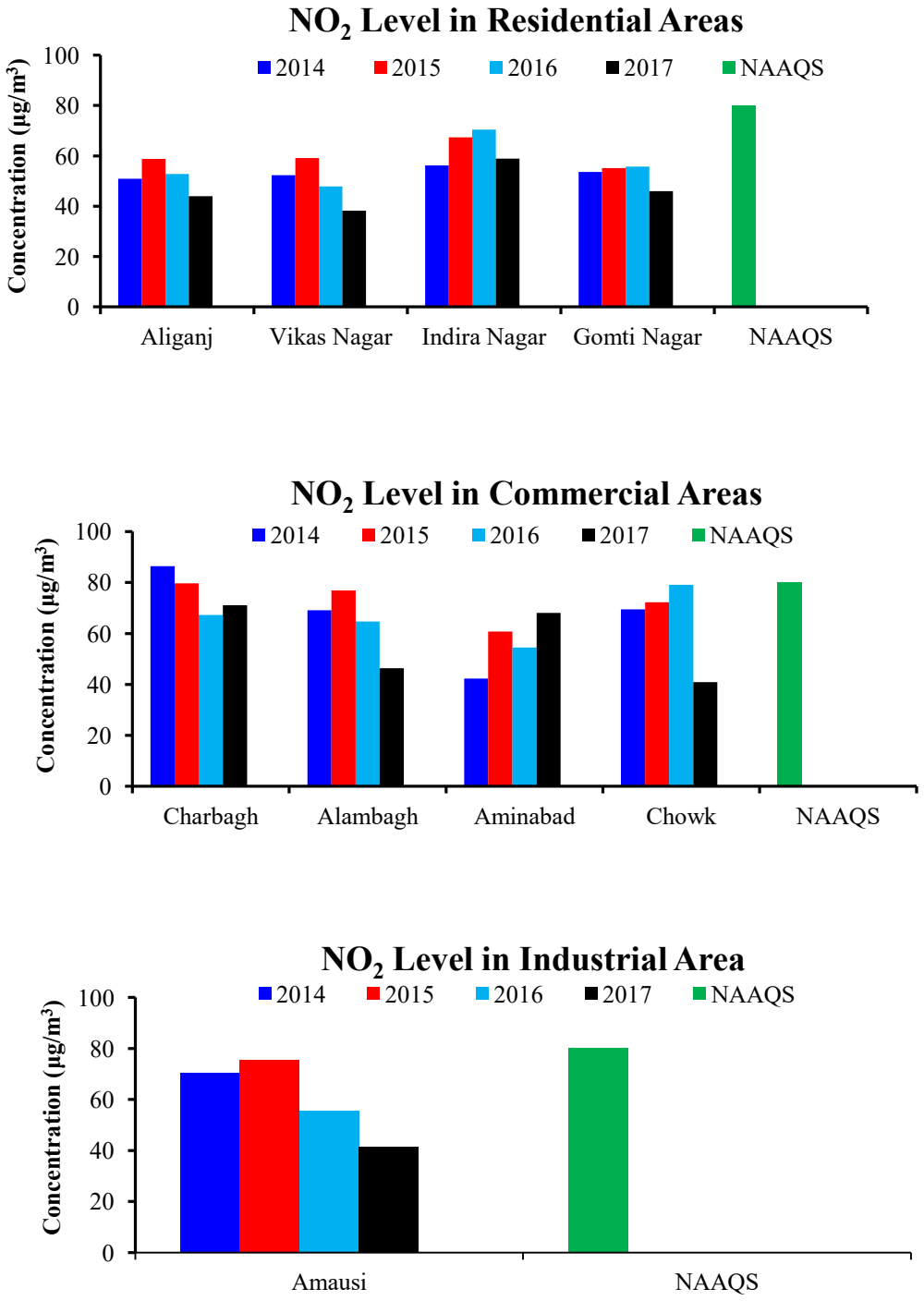

Figure 6: Concentration (µg/m^3) of NO_2 in Residential, Commercial and Industrial areas of Lucknow city during 2014 to 2017 and comparison with prescribed National Ambient Air Quality Standard (NAAQS)

1.4.4 Noise Level

Current year's noise data has been compared with the corresponding data of the previous three years and is presented in Fig.7 and Fig.8. Comparative noise level in residential, commercial and industrial areas are described below:

1.4.4.1 Day time Noise Level

In residential areas two locations showed slightly increasing trend over the previous year whereas the other two showed a decreasing trend. In commercial cum traffic areas, noise level was slightly on the lower side at all the locations compared to the previous year except Aminabad. In industrial area, Amausi the noise level was higher than the previous year. All noise levels surpassed the standards prescribed depending on the location. The comparative data are presented in (Fig.7).

1.4.4.2 Night time Noise Level

Residential, commercial as well as industrial areas showed higher trend for night time noise level than the last year level. All noise levels surpassed the standards prescribed depending on the location. The comparative data is presented in (Fig.8).

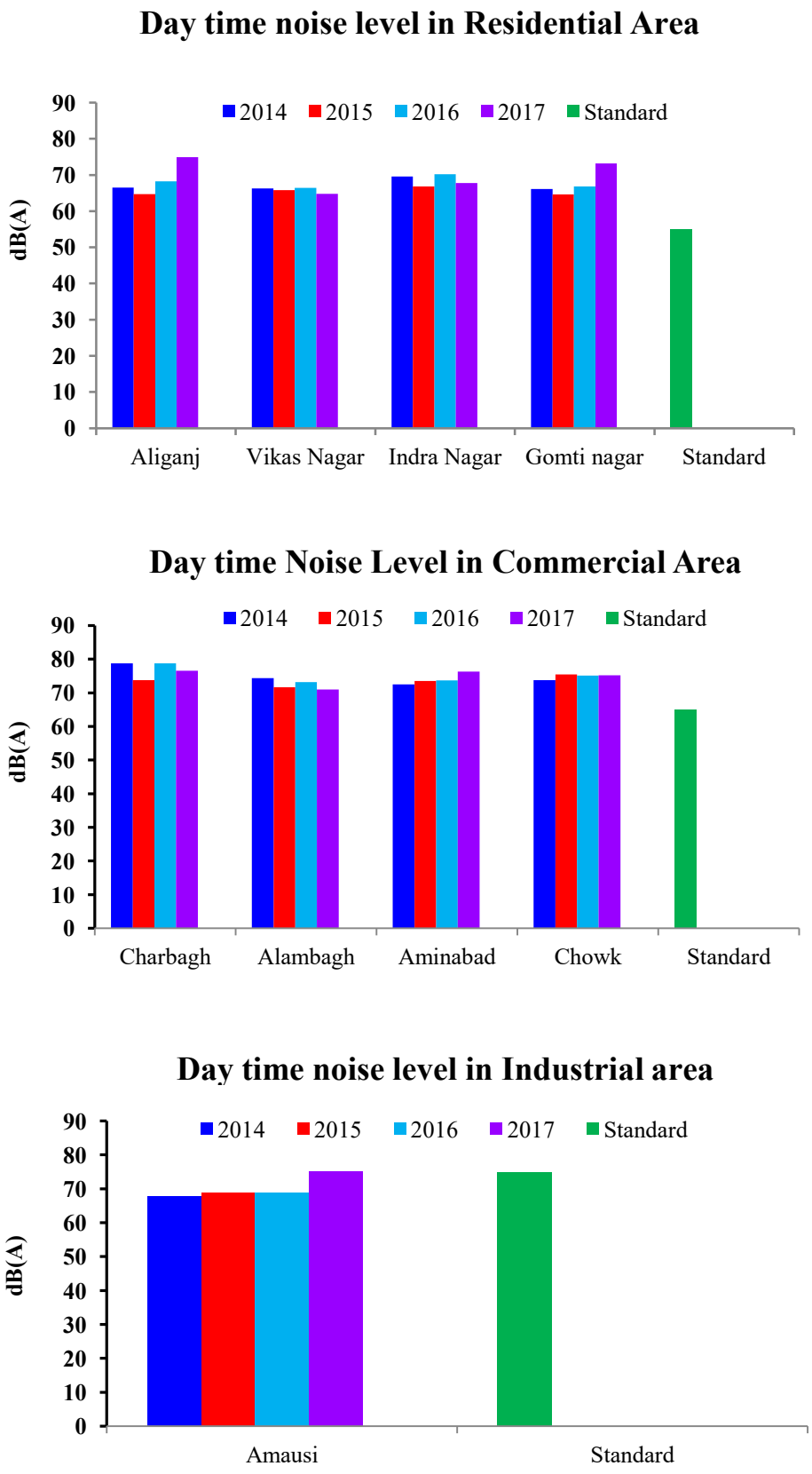

Figure 7: Comparison of day time Noise Level dB (A) in different areas of Lucknow city (2014-2017)

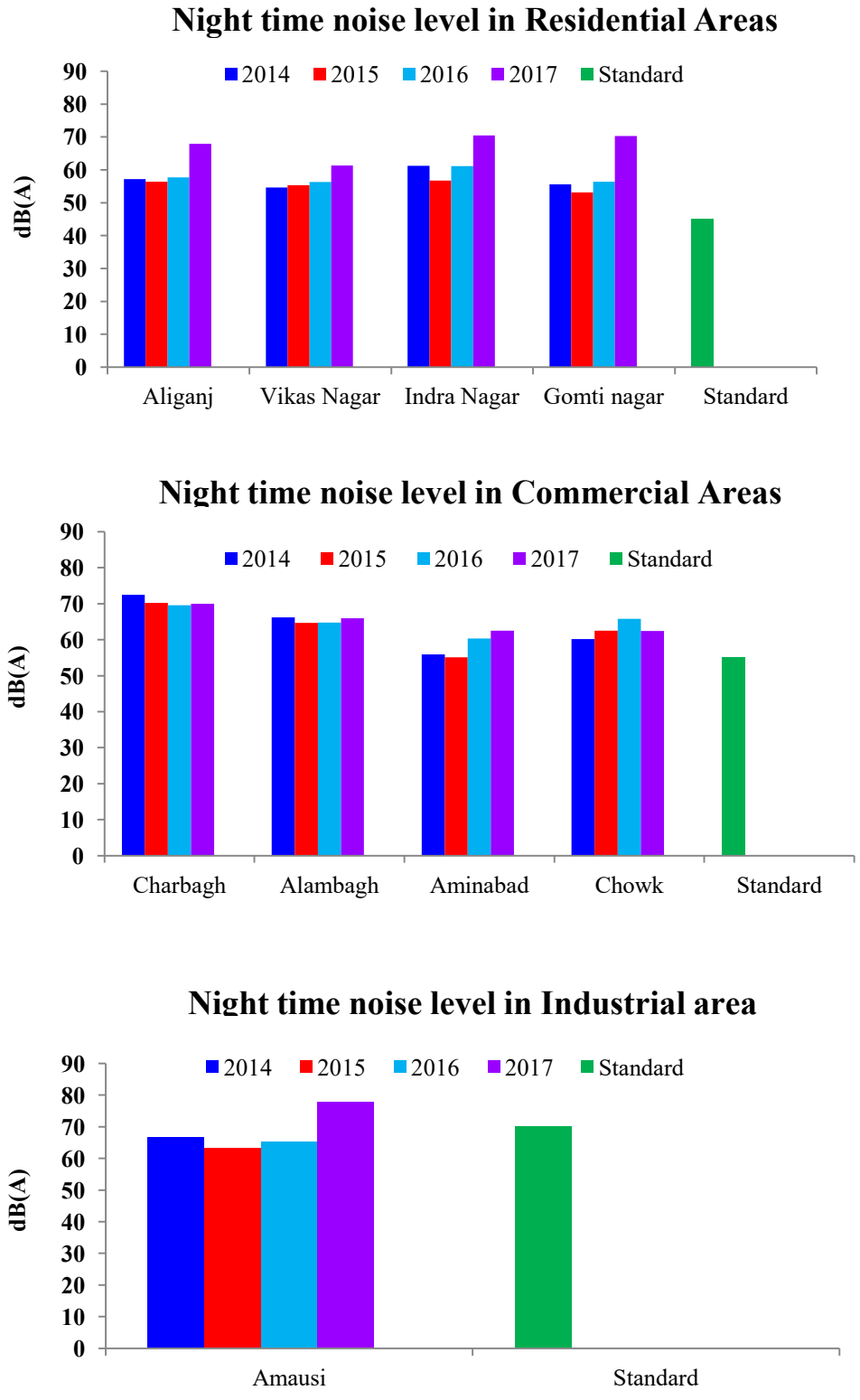

Figure 8: Comparison of night time Noise Level dB (A) in different areas of Lucknow city (2014-2017)

1.5 HEALTH EFFECTS

At elevated levels, all the pollutants including metals have adverse effects on human and environmental health. Accumulation of pollutants in the human body through inhalation of air is an important route. Individuals with heart diseases, lung diseases such as COPD, pregnant women, elderly people and infants are more susceptible to environmental pollution. Results of the present study revealed that higher level of particulate matter (PM_{10}) 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, accelerated aging of the lung cells etc., reproductive abnormalities, increased risk of preterm birth and even mortality and morbidity rate. It is reported that the total daily mortality increases by approximately 1% for every 10 $\mu g/m^3$ increase in PM_{10} concentration.

Human exposure to particulate air pollution has been identified as a risk factor for human mortality and morbidity and many countries have revised the limits for PM_{10} as previously defined and set up 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. Therefore, it is difficult to establish a standard or a guideline value that will lead to complete protection of every individual against all possible adverse health effects of particulate matter.

The effect of PM depends on the mass and number concentration, shape and size and the composition and concentration of other inorganic and organic pollutants associated with it. Metals Ni, Pb and As can cause cancer through inhalation of fine particles.

PM_{10} represents the particle mass that enters the respiratory tract and, moreover, it includes both the coarse (particle size between 2.5 and 10 μm) and fine particles (measuring less than 2.5 μm, $PM_{2.5}$) that are considered to contribute to the health effects observed in urban environments. Ultrafine particles (UFPs), i.e. particles smaller than 0.1μm in diameter, have recently attracted significant scientific and medical attention (WHO, 2005). While there is considerable toxicological evidence of potential detri-

mental effects of UFPs on human health, the existing body of epidemiological evidence is insufficient to reach a conclusion on the exposure–response relationship of UFPs. Therefore no recommendations can be provided as to guideline concentrations of UFPs at this point in time.

In the present study, the concentration of SO_2 and NO_2 were found to be below permissible limit (80 µg/m^3) of NAAQS (MoEF 2009), but there are several reports that gaseous pollutants are related with respiratory diseases and 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 recognized worldwide 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). Damage 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 socio-cultural, aesthetic, and economic effects.

1.6 CONCLUSION

Air pollutants such as PM_{10}, $PM_{2.5}$, SO_2 and NO_2, particulate trace metals and day v/s night noise level were monitored in order to assess the ambient air quality at 9 locations and sub fraction of fine particles at two locations, during post monsoon (Last week of September to October), 2017 and the data revealed the following salient points:

- The RSPM (PM_{10}) and Fine Particle ($PM_{2.5}$) level at all the monitoring locations of residential, commercial and industrial areas were higher than the National Ambient Air Quality Standard (NAAQS).

- The concentration of gaseous pollutant, SO_2 was well below the prescribed NAAQS (80 µg/m^3) at all the locations.

- The concentration of gaseous pollutant, NO_2 was below the prescribed NAAQS (80 µg/m^3) at all the locations.

- The sub-fractions of fine particles clearly indicated that mass of particulate matter decreased with the size. Total mass concentrations of all five sub-fractions of fine particles were found to be higher in commercial area. For these sub-fraction particles, no International and National guideline is available at this point of time.

- The concentration of PM_{10} and $PM_{2.5}$ were showing increasing trend when compared with last year data with few exceptions. Whereas in case of SO_2 and NO_2 were found to be decreasing (trend) to the previous year data except NO_2 for Aminabad and Charbagh.

- The noise levels at all the locations showed a mixed trend with night time values all locations being way higher than the previous year.

- Further it is relevant to mention that Diwali day was celebrated on 19th October, 2017 and the air quality was also monitored with the same parameters on pre Diwali, Diwali and post Diwali day and alarmingly higher levels of PM_{10} and $PM_{2.5}$ were recorded. Short-term adversely changed quality of air due to fire works has been highlighted in our report released separately and the monitoring results have not been included in this report (Diwali report is available as Annexure 1 and on CSIR-IITR website).

- Pre and post monsoon survey 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. Particulate matter is a carrier 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 are under continuous exposure to air pollutants and under the threat of health risks especially children, aged and the diseased.

- 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 introduction of metro rail in the city is a positive step towards reducing the air pollution, through the decrease in vehicular density which clearly indicates a positive co-relation between the severity of the traffic and air pollution.

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 post monsoon monitoring survey might be of help to focus on the pollution level in Lucknow city and its probable consequences. Our database since 1997 will help the planners for sustainable development of the city.

1.7 RECOMMENDATIONS FOR MITIGATION OF AIR POLLUTION

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

Acknowledgements:

We acknowledge Analytical Chemistry Division., CSIR-IITR, for analytical and technical support. We express our sincere thanks to Mr. A. K. Tripathi, Regional Transport Officer and Mr. Raghavendra Singh RTO Administration, Transport Nagar, Lucknow; Mr. D. K. Garg, Regional Manager, Lucknow City Transport Services Limited, Gomti Nagar, Lucknow; Mr. Tribhuban Pandey, Sr. Manager, Retail sales, Indian Oil Corporation (IOC), Lucknow; Mr. Anilesh Kumar, Sr. Manager, Retail Initiatives (U.P.), Bharat Petroleum Corporation Ltd. (BPCL), Lucknow, Mr. Prakash Kumar Bhaduria, Chief Regional Manager, Hindustan Petroleum Corporation Limited (HPCL), Lucknow and Mr. Surya Prakash Gupta, Chief Manager (Marketing), 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.

Annexure-I

Assessment of Ambient Air Quality during Pre-Diwali, Diwali and Post-Diwali Festival, October 2017

Assessment of Ambient Air Quality during Pre-Diwali, Diwali and Post-Diwali Festival, October 2017

Environmental Monitoring Division
CSIR-Indian Institute of Toxicology Research
Vishvigyan Bhawan, 31 Mahatma Gandhi Marg, Lucknow – 226001, UP

CSIR-Indian Institute of Toxicology Research (CSIR-IITR), Lucknow conducted Air Quality survey at 7 locations (Aliganj, Vikasnagar, Indiranagar, Gomtinagar, Charbagh, Aminabad and Chowk) of Lucknow city to assess the impact of fireworks on the environment during the Diwali festival, 2017. Monitoring 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 (Table 1).

During the major event on Diwali night October 19th, 2017 the mean level of $PM_{2.5}$ increased from 180.3 to 316.0 $\mu g/m^3$ over the pre-Diwali night and reduced to 183.6 $\mu g/m^3$ during post-Diwali night. Similarly on Diwali night, the level of PM_{10} also increased from 257.9 to 514.8 $\mu g/m^3$ over the pre-Diwali night and reduced to 295.3 $\mu g/m^3$ during post-Diwali night. The bursting of crackers is responsible for the increasing trend of particulate levels as the other sources such as traffic and industrial activities were at the minimal contribution levels during the period on account of Diwali holidays.

On the Diwali night $PM_{2.5}$ increased by 75.3% whereas the increase in PM_{10} over the pre-Diwali night was 99.6%. Further, the higher levels of particulates continued during post-Diwali night by 1.8% and 14.5% for $PM_{2.5}$ and PM_{10} respectively over pre-Diwali night levels (Fig. 1).

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 10.8 to 22.3 $\mu g/m^3$ and on post-Diwali mean SO_2 level was 15.8 $\mu g/m^3$, which indicates that the levels increased by107.0% and 46.4% 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 45.2 to 54.4 $\mu g/m^3$ over the pre-Diwali night. On the post-Diwali night, mean level of NO_2 was decreased to 37.9 from 45.2 $\mu g/m^3$ on pre Diwali night. In terms of percentage, NO_2 level increased by 20.4% on Diwali night and decreased by 16.2 % on post-Diwali night over the pre-Diwali night.

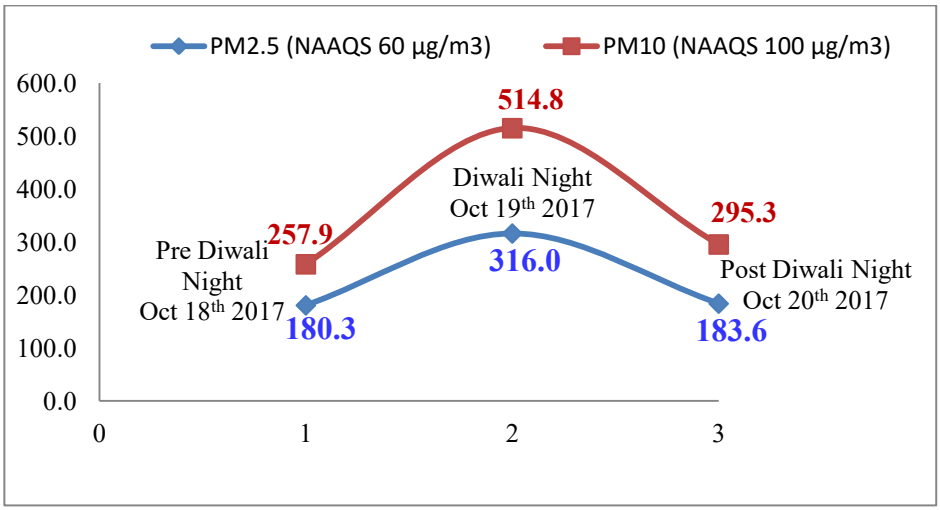

Fig. 1. Profile of respirable particulates during the night time of Diwali festival

The meteorological conditions, particularly wind speed and directions play a major role in the transport and dispersion of the pollutants from their source. Based on CPCB monitoring data at Lalbagh, Lucknow the wind speed ranged between 0.14 to 0.91 meter per second (m/s) with an average of 0.49 m/s during 09 AM (19/10/2017) to 5 AM (20/10/2017). The prominent wind direction was ENE (East North East).

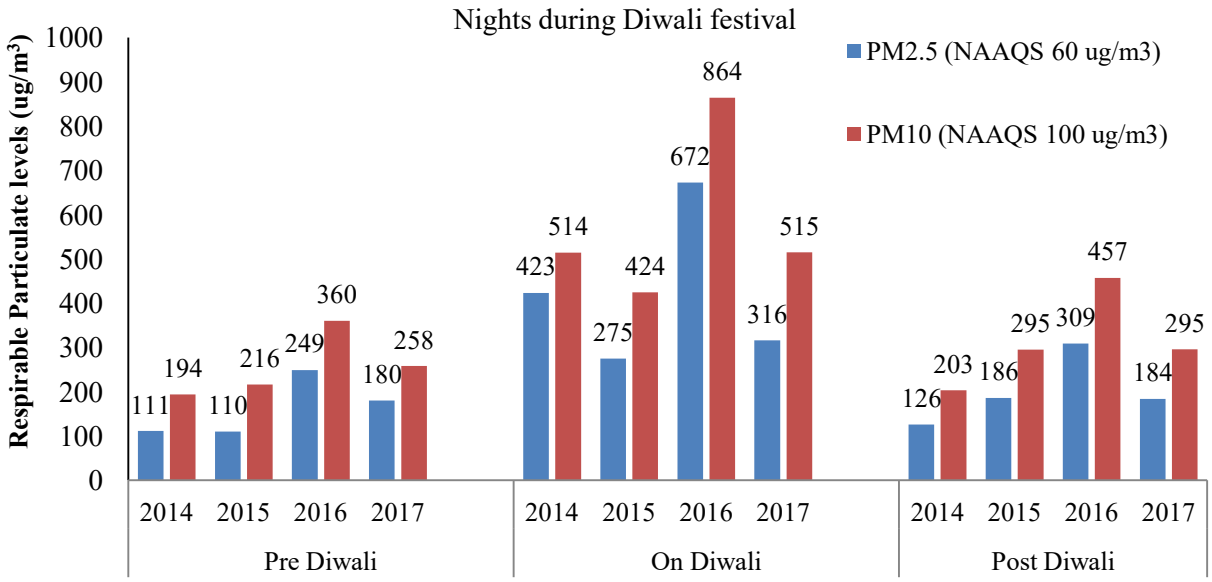

Fig. 2. Levels of respirable particulates (PM_{10} and $PM_{2.5}$) concentration during 2014, 2015, 2016 and 2017 (Diwali festival)

Table 1. CSIR-IITR Diwali 2017 pollution survey

Pollutants/ Locations	**pre-Diwali 2017** (October 18th, 2017)		**on-Diwali 2017** (October 19th, 2017)		**post-Diwali 2017** (October 20th, 2017)	
PM_{10} **(**$\mu g/m^3$)	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)
Aliganj	195.1	229.3	214.8	427.2	186.6	308.9
Vikas Nagar	190.7	307.2	239.6	752.6	167.2	313.8
Indira Nagar	202.3	224.7	208.5	548.8	196.8	318.7
Gomti Nagar	ND	246.1	202.7	422.1	176.9	291.6
Charbagh	133.0	319.4	303.1	581.4	207.8	302.7
Aminabad	226.6	254.7	246.3	494.5	177.1	290.5
Chowk	200.4	224.0	171.9	376.8	169.6	241.2
$PM_{2.5}$ ($\mu g/m^3$)						
Aliganj	117.5	163.1	149.3	297.1	128.8	177.8
Vikas Nagar	150.1	226.2	154.7	438.9	119.0	198.1
Indira Nagar	120.3	153.1	175.7	285.0	126.4	194.6
Gomti Nagar	166.1	180.4	147.6	280.8	99.5	156.8
Charbagh	173.4	233.7	162.3	401.1	128.3	211.8
Aminabad	164.1	178.6	174.8	281.3	123.9	180.5
Chowk	106.5	127.2	129.4	228.0	118.2	165.9
SO_2 ($\mu g/m^3$)						
Aliganj	7.1	9.7	12.2	20.8	6.8	15.8
Vikas Nagar	10.6	12.1	8.6	31.3	7.1	18.5
Indira Nagar	12.7	13.9	10.9	25.1	10.7	17.1
Gomti Nagar	ND	8.1	11.5	21.8	6.9	14.4
Charbagh	10.7	13.3	10.8	24.0	9.8	19.3
Aminabad	9.1	8.1	11.1	19.3	7.0	13.4
Chowk	8.8	10.2	8.6	13.8	7.2	11.9
NO_2 ($\mu g/m^3$)						
Aliganj	39.5	42.2	43.4	51.5	27.2	35.6
Vikas Nagar	23.5	30.2	43.0	72.4	25.1	39.1
Indira Nagar	37.4	44.0	63.6	62.9	35.1	42.2
Gomti Nagar	ND	33.8	23.3	37.9	20.9	35.9
Charbagh	78.4	71.3	90.4	67.5	38.2	46.8
Aminabad	49.5	40.1	32.9	44.3	24.6	34.2
Chowk	51.6	54.8	47.9	44.6	27.3	31.2

ND= Not Done

Noise Level

Noise level was recorded during pre-Diwali, post-Diwali and on Diwali night to observe 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 noise level was recorded as 82.8 dB(A) at Vikas Nagar area whereas minimum was recorded as 70.3 dB(A) at Gomti Nagar on Diwali night. The sound waves generated from the bursting of crackers at a level higher than 80 dB(A), may damage eardrum and may induce temporary or permanent deafness. Exposure to high levels of noise may trigger problems like annoyance, irritation, hypertension, stress, hearing loss, headache and sleep disturbance. The recorded noise levels are given in Table 2.

Table 2. Noise Level on pre-Diwali, Diwali and post-Diwali night

Locations	**pre-Diwali** (October 18th, 2017)	**on-Diwali** (October 19th, 2017)	**post-Diwali** (October 20th, 2017)
	Noise dB(A)		
Charbagh (10:0-10:30 PM)	70.3	80.1	71.5
Chowk (8:30 to 9 :00 PM)	72.1	77.9	68.9
Aliganj (10:30 to 11 PM	66.4	78.5	68.4
Vikas Nagar (9:45-10:15 PM)	60.7	82.8	66.8
Indira Nagar (9:0-9:30 PM)	69.1	78.4	68.4
Gomti Nagar (11:30 - midnight)	64.5	70.3	62.5

The CSIR-IITR mission towards pollution free environment and minimizing/ regulating the use of crackers is an integral part of all activities/ exhibitions and programmes amongst the students, family members of staffs, general public and media persons. 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 could severely affect human health particularly in case of children, senior citizens and people with respiratory issues. In general, fire cracker contains various elements like aluminum, antimony sulphide, perchlorate, barium nitrate, lithium, copper, strontium, cadmium etc., which are responsible for causing Alzheimers' disease, thyroid, gastrointestinal problems, muscular weakness, respiratory problems, hormonal disbalance etc. It may even cause cancer. Therefore the firing of crackers should be discouraged during Diwali.