Assessment of Ambient Air Quality of Lucknow City

Post-Monsoon 2019

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ABBREVIATIONS

AQI – Air Quality Index
BPCL – Bharat Petroleum Corporation Ltd.
Ca – Calcium
Cd - Cadmium
CNG – Compressed Natural Gas
CO – Carbon Monoxide
Co – Cobalt
CPCB – Central Pollution Control Board
CSIR-IITR- Council of Scientific and Industrial Research- Indian Institute of Toxicology Research
Cu – Copper
Fe – Iron
FPM- Fine Particulate Matter
HC – Hydrocarbon
HPCL – Hindustan Petroleum Corporation Ltd.
IOC – Indian Oil Corporation
K – Potassium
KGMU – King George's Medical University
LDA – Lucknow Development Authority
LMRC – Lucknow Metro Rail Corporation
LNG – Liquefied Natural Gas
Mg – Magnesium
Mn – Manganese
Na – Sodium
NAAQS – National Ambient Air Quality Standards
Ni – Nickel
NO_2 – Nitrogen Dioxide
O_3 – Ozone
PAH – Poly Aromatic Hydrocarbons
Pb – Lead
PM – Particulate Matter
RSPM – Respirable Suspended Particulate Matter
RTO – Regional Transport Office
SO_2 – Sulphur Dioxide
UPSRTC – Utter Pradesh State Road Transport Corporation
WHO – World Health Organization
Zn – Zinc

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**	:	28,15,033 as per 2011 Census
❖ **Projected Population**	:	65 lakhs as per Master Plan 2031 (www.ldaonline.in)
❖ **General Climate of Lucknow city**	:	Subtropical climate, cool dry winter (Dec. - Feb.) & summer (Mar. - Jun.). Temperature about 45°C in summer to 3°C in winter. Average annual rainfall about 100 cm.
❖ **Total Vehicular Population of Lucknow city as on 31/03/2019**	:	21,94,261
❖ **Growth of Vehicle over 2017-2018**	:	9.24%
❖ **Total No. of Filling Stations (Petrol/Diesel/CNG)**	:	101
❖ **Consumption of Petrol**	:	2,25,508 kL
❖ **Consumption of Diesel**	:	2,19,944 kL
❖ **Consumption of CNG**	:	4,70,44,857 Kg
❖ **Major Sources of Pollution**	:	Automobiles, D.G. Sets, biomass burning, Construction activities
❖ **Parameters Monitored**	:	PM_{10}, $PM_{2.5}$, SO_2, NO_2, Trace elements and Noise Levels
❖ **Study Conducted by**	:	Environmental Monitoring Division CSIR-IITR, Lucknow

ASSESSMENT OF AMBIENT AIR QUALITY OF LUCKNOW CITY DURING POST-MONSOON, 2019

1.0 SUMMARY

The study was carried out during the months of October-November, 2019 to assess the status of air quality by monitoring and assessment of some selected air pollutants namely RSPM or PM_{10}, FPM or $PM_{2.5}$, SO_2, NO_2, trace elements and noise level at 9 representative locations, categorized as residential (four), commercial (four) and industrial (one) areas in Lucknow city. The results of the study are presented in three phases, phase-1 before Deepawali (From October- 1st week to 3rd week, phase–II (during Deepawali festival, 26th to 29th October) and phase-III (after Deepawali during 1st week of November 2019). The results for phase -1 revealed the 24 hours concentration of PM_{10} to be in the range of 63.8 - 313.3 $\mu g/m^3$ with an average of 159.0 $\mu g/m^3$. The 24 hours concentration of $PM_{2.5}$ was found to be in the range of 32.0 - 199.0 $\mu g/m^3$ with an average of 80.1 $\mu g/m^3$. The average values of PM_{10} and $PM_{2.5}$ irrespective of locations were found to be above the permissible limit (100 $\mu g/m^3$ for PM_{10} and 60 $\mu g/m^3$ for $PM_{2.5}$ prescribed by CPCB, 2009). Twenty four hours concentration of SO_2 and NO_2 were found to be in the range of 3.1 - 22.7 and 17.1 - 85.6 $\mu g/m^3$ with average concentrations of 10.2 and 35.4 $\mu g/m^3$ respectively and all the mean values were below the permissible limit (80 $\mu g/m^3$ for both SO_2 and NO_2 prescribed by CPCB, 2009). The mean level of trace elements were; Pb=47.12, Ni=14.57, Cd=3.32, Cu=9.04, Zn=130.28, Co=3.41, Mn=20.58, Fe=494.54, Ca=2682.44, Mg=486.24, Na=18962.32 and K=739.57 ng/m^3. *Noise levels during day and night time were found to be in the range of 65.9 - 77.2 dB(A) and 58.0 - 68.9 dB (A) respectively which was above the respective permissible limits. The results for phase-II (during Deepawali festival) have already been published and are available at CSIR-IITR website and also enclosed as Annexure-1. Two days phase-III monitoring results revealed the 24 hours concentrations of PM_{10} to be in the range of 367.9 - 579.8 $\mu g/m^3$. $PM_{2.5}$ was found to be in the range of 174.1 - 401.8 $\mu g/m^3$, whereas SO_2 and NO_2 values of all the locations were found to be in the range of 5.8 - 23.6 and 40.3 - 184.8 $\mu g/m^3$ respectively. After Deepawali, concentration of PM_{10}, $PM_{2.5}$, SO_2 and NO_2 were found comparatively 194.1, 257.0, 17.1 and 147.7% higher than before Deepawali festival levels respectively.*

1.1 INTRODUCTION

There is a direct link between air pollution and human health hazards. Thus, air pollution is a serious issue in the present context that needs to be addressed very sincerely. A large numbers of people particularly in the urban areas are exposed to the high levels of air pollution. As per WHO, worldwide about 92% people are exposed to higher level of air pollutants than the WHO recommended level.

The air pollutants such as $PM_{10,}$ $PM_{2.5}$, SO_2, NO_2, O_3, CO, HC and PAHs are a major concern with respect to human health effects. Some pollutants including PM, CO, CO_2 and HC have major impact on visibility and climate change, and its consequences have severe impacts on global warming as well as food safety.

The major sources of urban air pollution are burning of fossil fuel like petrol, diesel, CNG and LNG etc. by vehicles and generator sets, coal burning by the industries in and around the city area, burning of municipal solid waste etc. Besides, tyre-road surface friction dust, brake friction dust, re suspension of road side soil dust etc. create major impact on human health.

Once the air pollutants are released in the atmosphere they are subjected to diffusion, dilution, transport and chemical reactions. Thus air quality besides sources also depends on the condition of meteorological parameters (weather conditions) like temperature, wind speed and direction, relative humidity, storm, pressure, rainfall etc. and conversion of primary pollutants to secondary pollutants.

Further, high rise buildings and other structures influence the air quality by restricting the air flow, creating turbulence and micro climatic zones, preventing dispersion and depositing of air pollutants on the street canyons in the urban areas.

Several scientific studies suggest that human health affects due to air pollution are largely associated with cardio respiratory system which includes exacerbation of asthma, reduced lung function, myocardial infection and progression of atherosclerosis and cardio vascular disease. Although the individual pollutants are regulated with

compliance limits, the synergetic impact of these pollutants results in chronic and instant consequences.

In view of the above scope, CSIR-IITR has been carrying out air pollution monitoring for the Lucknow city during pre (April and May) and post (September and October) monsoon seasons each year since 1997. Usually Lucknow city has hot and humid climate with dry winds during the post -monsoon season (September and October). This year Lucknow observed an extended monsoon till September end, hence, the post monsoon survey commenced in the month of October. Therefore, phase I of the study was conducted from 1st to 3rd week of October 2019, phase II of study was conducted as Deepawali survey from 26th to 29th October. 2019 and phase III was conducted after Deepawali festival in the first week of November 2019. Construction, industrial, commercial and road transportation activity based air borne particles mainly affect the city ambient air environment.

The metro run by Lucknow Metro Rail Corporation completed two years of its commercial services on 5th September 2019. Presently it is operating between Chaudhary Charan Singh International Airport to Munshipulia station. The metro operation has shown some positive impact on city air pollution along metro route as road traffic has reduced. Besides, recently constructed flyovers and expressways in and around the city also give a positive impact on reduction of air pollution levels of the city. However, recently evolved city infrastructure usage is yet to reach the benchmark as desired. Further, rapid growth of population concentration and their activities and larger demand for goods and services in Lucknow city lead to increased pollution. As per census of 2011, the Lucknow city has the population of 28.15 Lakh (Municipal Corporation + Cantonment) with an area of occupancy covering about 310 sq. km.

Vehicular traffic has been found to be the main source of particulate air pollution in Lucknow city. Lucknow city has become denser with traffic congestion which increases the vehicle emissions and subsequent health impact mainly for drivers, commuters, and individuals especially people living near roadways. The number of different categories of vehicles registered with RTO Lucknow is 21,94,261 as on

31.03.2019 which is 9.24% higher over the last year (2018). Table 1 presents the comparison between vehicular populations of current and last year for Lucknow city. UPSRTC has introduced bus services under the banner "*Lucknow City Transport Services Limited*" on different routes of Lucknow city. The details of bus routes and number of buses plying as on 31.03.2019 are given in Table 2. In Lucknow city there are 101 filling stations for petrol, diesel and CNG operated by different oil and gas companies. Table 3 presents the number of fuel outlets with corresponding agencies.

As per Oil Marketing Company (IOC, BPC and HPCL), the consumption/sale of petrol and diesel was 2,25,508 and 2,19,944 KL as on 31-03-2019. It has been observed that petroleum sale has increased by 8.04% whereas sale of diesel has increased by 4.83% (Table 4). In Lucknow there are nine CNG filling stations and consumption of CNG in the last year was approximately 4,70,44,857 kg (2018-19) which was 10.86% higher than the previous year (2017-18) (Green Gas Limited, Lucknow). Distribution and number of CNG vehicles in Lucknow is summarized in Table 5. The expansion of city is still continued, converting the land use from agricultural to residential/ commercial/ industrial. As a result, there has been an increase in air pollution levels of the city. Considering the above, assessment of ambient air quality of Lucknow city was carried out at nine locations during post monsoon (October and November, 2019) with respect to PM_{10}, $PM_{2.5}$, SO_2, NO_2, trace elements and noise levels with the following aims and objectives:

- *To assess the ambient air quality with respect to PM_{10}, $PM_{2.5}$, SO_2, NO_2, and trace elements associated with PM_{10}.*
- *To study trends of pollutants over a period of time.*
- *To assess day and night time noise levels.*
- *To create a database for future use.*
- *To create public awareness about environmental pollution.*

Table 1
Comparison of Vehicular Population in Lucknow

S.No.	Type of Vehicle	Number of Registered Vehicles as on 31st March		% Change
		2017-18	2018-19	
1	Multi Articulated	4379	5777	31.93
2	Light, Medium and Heavy weight Vehicles (Four wheeler)	29454	42318	43.67
3	Light commercial vehicles (Three wheeler)	3601	3482	-3.30
4	Buses	3538	3876	9.55
5	Omni Buses	440	489	11.14
6	Taxi	17554	24851	41.57
7	Light Motor Vehicles (Passenger)	7929	8191	3.30
8	Two wheelers	1590913	1708874	7.41
9	Motorcycle on hire	81	377	365.43
10	Car	278938	297774	6.75
11	Jeep	37863	62398	64.80
12	Tractor	25309	26902	6.29
13	Trailors	1858	1946	4.74
14	Others	6854	7006	2.22
Total		**20,08,711**	**21,94,261**	**9.24**

Source: RTO, Lucknow

Table 2
Details of Lucknow City Bus Service, 2019

S. No.	Route No.	To and Fro	No. of Buses	Frequency
1	11	BBD – Dayal- Residency-Matiyari Tiraha-Petrolpump-Chinhat-Kathauta-M T Hahnemann- Judicial- Husadiya-Maliktimber-Patrakarpuram- P S Gomti Nagar Vishalkhand-CMS-Vipulkhand-Ambedkar Smarak-BBD Academy- Jansatta-Lohiya Park-FunRepublic-Baluadda-MM Malviya- Tikoniya Park- Dainik Jagaran- Sikanderbagh-Jawahar Bhavan- Shakti Bhavan-GPO- Bapu Bhavan-Burlington- Hussainganj-Vikasdeep-KKC- Charbagh.	10	10 minute interval
2	12M	Charbagh – KKC- Vikas Deep-Husainganj-Burlington—Bapu Bhawan- GPO-Ayakar Bhavan-Shakti Bhawan- Jawahar Bhavan-Sikanderbagh- Gokhle Marg-Nishatganj-Gole Market-Badshahnagar-Polytechnique-Kamta-Chinhat-Telco-Samarpan.	7	20 minute interval
3	12A	Anaura Chowki-Sharda Nahar-Ram Swaroop College-Tiwariganj-BBD- Dayal residency-Matiyari Tiraha-Petrol Pump-Chinhat Mod-Kamta- Surendra Nagar-Ismailganj- sector 8- Polytechnique- Lohiya Park- 1090 Chauraha- Baluadda - Dainik Jagaran- Sikanderbagh-Jawahar Bhavan- Shakti Bhavan-GPO- Bapu Bhavan- Hussainganj-Vikasdeep-KKC- Charbagh.	16	20 minute interval
4	15S	Kamta Chowraha- Husadiya- Cricket Stadium-Aahimau-Awadh Shilp Gram-Uttarathia-Transport Nagar- Nadarganj-Sainik School-Gauri Bazaar- Scooter India.	13	10 minute interval
5	15T	Ravindralaya- Alambagh Thana- Anand Nagar-Banglapur-Telibagh-Uttarathia- Awadh Shilp Gram- Aahimau- Cricket Stadium-Husadiya- Kamta Chowraha.	4	35 minute interval
6	23	Integral University-Gudamba-Vikasnagar– Nishatganj Paper Mill-Gokhale marg-Sikandarbagh- Jawahar Bhavan- Shakti Bhavan-GPO-Bapu Bhavan-Burlington- Hussainganj-Vikasdeep-KKC- Charbagh-Mawaiya-PS Alambagh- Tedhipuliya- Bus Station-Alambagh Chauraha- Ramnagar- Puran Nagar- Sringarnagar- Awadh Hoapital-Barabirwan-Pasoquila charaha- Rajni Khand.	18	20 minute interval
7	31	IIM- Sector Q-Beligaradh-PNT-Purania- Regional Science Centre-Kapporthala-Channilal-Mahanagar-Gole Market-Badshanagar-Nishaganj-Paper Mill- Ghokhale marg-Sikandarbagh- Jawahar Bhavan- Shakti Bhavan-GPO- Bapu Bhavan-Burlington-Hussainganj-Vikasdeep-KKC- Charbagh.	1	113 minute interval

8	33	Engineering College-Sector Q-Beligaradh-PNT-Purania- Regional Science Centre-Kapporthala-Channilal-Mahanagar-Gole Market-Badshanagar-Nishaganj-Paper Mill-Gokhale marg-Sikandarbagh-Jawahar Bhavan- Shakti Bhavan-GPO- Bapu Bhavan-Burlington-Hussainganj-Vikasdeep-KKC- Charbagh- Mawaiya-PS Alambagh-Tedhipuliya- Bus Station-Alambagh Chauraha- Ramnagar- Puran Nagar- Sringarnagar- Awadh Hospital-Krishna Nagar- Transport Nagar- Nadarganj-Scooter India.	5	30 minute interval
9	33C	Bhitoli Chauraha- CDRI Chowraha – Mulayam Chauraha-Engineering College- Kapoorthala- Gole market-Sikandrabadh-GPO-Bapubhavan- Hussainganj –KKC- Charbagh.	5	30 minute interval
10	33P	Engineering College-Sector Q-Beligaradh-PNT-Purania- Regional Science Centre-Kapporthala-Channilal-Mahanagar-Gole Market-Badshanagar-Nishaganj-Paper Mill-Gokhale marg-Sikandarbagh-Jawahar Bhavan- Shakti Bhavan-GPO- Bapu Bhavan-Burlington-Hussainganj-Vikasdeep-KKC- Charbagh- Mawaiya-PS Alambagh-Tedhipuliya- Bus Station-Anand Nagar-Banglapur-Shiv Mandir-Telibagh- Uthretia- South City- PGI.	5	35 minute interval
11	43H	Viraj Khand- Hahnemann Chauraha-New High Court- -Polytechnic Chowraha- Munshiphulia-Khuramnagar Chowraha-Jagrani Chowraha-Tedhipulia- Engineering College-Madiaon- Bhitoli-Sahara City-Dubagga Chowraha.	3	25 minute interval
12	45	Virajkhand – Hahnemann- MT Kathauta-Vikrant Kahnd- Vijaypur-IndiraGandhi Prathisthan –Lohia Hospital-Picup-Polytechnic-HA.L.-Bhoothnath- Nilgiri-Lekhraj- Shaktinagar- Badshahnagar-Nishatganj-Papermil- Gokhale marg-Sikandarbagh- Jawahar Bhavan-Shakti Bhavan-GPO- Bapu Bhavan-Burlington- Hussainganj-Vikasdeep-KKC- Charbagh- Mawaiya-PS Alambagh- Tedhipuliya-Bus Station- Alambagh Chauraha- Ramnagar- Puran Nagar-Sringarnagar- Awadh Hospital-Krishna Nagar-Awadh College-Purani Chungi-Hindnagar- Shivdev-Paragdairy- Parag terminal-Nageshwar-Sector N-Pasiqiula- Ambedkar University.	8	20 minute interval
		Total	95	

Source: Lucknow City Transport Services Limited.

Table 3
Fuel Outlets in Lucknow City

S.No.	Agency	Number of outlets as on 31st March 2019
1	Indian Oil Corporation (IOC)	41
2	Bharat Petroleum Corporation Ltd. (BPCL)	23
3	Hindustan Petroleum Corporation Ltd. (HPCL)	28
4	Compressed Natural Gas Stations (CNG)	13
Total		**101**

*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

Sl. No.	Agency	Petrol in kL			High Speed Diesel in kL			CNG in Kg		
		Apr. 17 to Mar. 18	Apr. 18 to Mar. 19	% Change	Apr. 17 to Mar. 18	Apr. 18 to Mar. 19	% Change	Apr. 17 to Mar. 18	Apr. 18 to Mar. 19	% Change
1	IOC	105428	105516	0.08	88648	86203	-2.76	--	--	--
2	BPCL	49115	63144	28.56	54533	63457	16.36	--	--	--
3	HPCL	54193	56848	4.89	66620	70284	5.49	--	--	--
4	Green Gas	--	--	--	--	--	--	42437108	47044857	10.86
Total		**208736**	**225508**	**8.04**	**209801**	**219944**	**4.83**	**42437108**	**47044857**	**10.86**

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

Table 5
Distribution of CNG Vehicles

S. No.	Vehicles	Number		% of Change
		2017-18*	2018-19	
1	Auto Rickshaws	4343	4343	--
2	Tempo Taxi	2575	2575	--
3	Buses (UPSRTC)	260	260	--
4	Buses (Private)	40	40	--
5	School Buses	1237	1253	1.29
6	School Van	1914	1946	1.67
7	Private Vehicles	205	205	--
8	Private Cars	11575	11885	2.67
	Total	**22,149**	**22,507**	**1.62**

Source: RTO, Lucknow, Green Gas Limited, 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 and Figure 1 and adopted methodologies are given in Table 7.

Table 6
Monitoring Locations

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

Table 7
Parameters and Methodology for Air Quality Monitoring

Sl. No.	Parameters	Time Weighted Average	Methods of Measurement
1	Particulate Matter (PM_{10})	24 hours	Gravimetric
2	Fine Particles ($PM_{2.5}$)	24 hours	Gravimetric
3	Sulphur dioxide (SO_2)	24 hours	Improved West Gaeke
4	Nitrogen Dioxide(NO_2)	24 hours	Modified Jacob & Hochhesier (Na-Arsenite)
5	Trace Elements	24 hours	AAS method after sampling on EPM 2000
6	Noise Level	1 hour	The measurement of noise level was carried out during the day (6 AM to 10 PM) and night time (10 PM to 6 AM) by Noise Level Meter

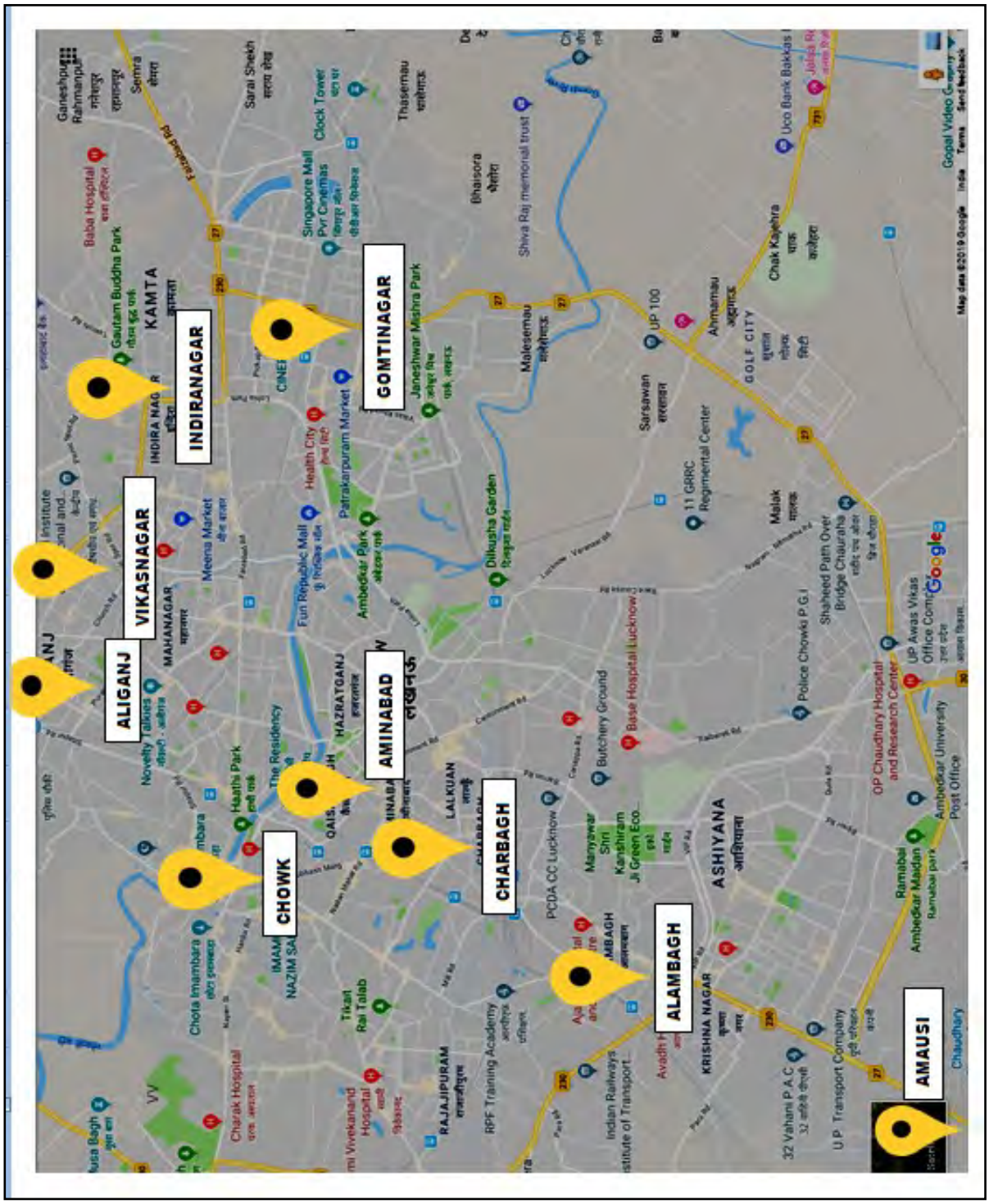


Figure 1: Ambient Air Pollution Monitoring Locations in Lucknow City

1.3 RESULTS

The detailed results of air quality monitoring for phase I are presented in Table 8 and Figure 2 and phase III in Table 9 and Figure 3.

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

Phase I

In residential areas (Aliganj, Vikas Nagar, Indira Nagar and Gomti Nagar), the 24 hours average concentrations of PM_{10} were in the range of 142.9 to 165.4 µg/m^3 with an average of 154.0 µg/m^3. In commercial areas (Charbagh, Alambagh, Aminabad and Chowk) the average concentrations of PM_{10} were in the range of 138.6 to 197.4 µg/m^3 with an average of 165.4 µg/m^3 respectively. In industrial area (Amausi), the average concentration of PM_{10} was 153.7 µg/m^3.

The maximum 24 hours mean concentration of PM_{10} was observed in Gomti Nagar (165.4 µg/m^3) in residential area and Charbagh (197.4 µg/m^3) in commercial areas. All the values of PM_{10} were above the prescribed National Ambient Air Quality Standard (NAAQS) of 100 µg/m^3 (standard for industrial, residential, rural and other areas) respectively.

Phase III

In residential areas (Aliganj, Vikas Nagar, Indira Nagar and Gomti Nagar), the 24 hours average concentrations of PM_{10} were in the range of 386.3 to 496.6 µg/m^3 with an average of 441.3 µg/m^3. In commercial areas (Charbagh, Alambagh, Aminabad and Chowk) the average concentrations of PM_{10} were in the range of 471.7 to 513.2 µg/m^3 with an average of 499.8 µg/m^3 respectively. In industrial area (Amausi), the average concentration of PM_{10} was 425.2 µg/m^3.

The maximum 24 hours mean concentration of PM_{10} was observed in Aliganj (496.5 µg/m^3) in residential area and Charbagh (513.2 µg/m^3) in commercial areas.

Overall at 24 hrs mean level $PM_{2.5}$ concentration during 3rd phase was found to be 194.1% higher than the 1st phase.

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

Phase I

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 71.1 to 93.6 µg/m^3 with an average of 79.3 µg/m^3. In commercial areas (Charbagh, Alambagh, Aminabad and Chowk) the average concentrations of $PM_{2,5}$ were in the range of 66.5 to 109.6 µg/m^3 with an average of 80.9 µg/m^3 respectively. In industrial area (Amausi), the average concentration of $PM_{2.5}$ was 80.1 µg/m^3.

The maximum 24 hours mean concentration of $PM_{2.5}$ was observed in Gomti Nagar (93.6 µg/m^3) residential area and Charbagh (109.6 µg/m^3) in commercial area. All the values of $PM_{2.5}$ were above the prescribed NAAQS of 60 µg/m^3 for industrial, residential, rural and other areas.

Phase III

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 184.2 to 286.5 µg/m^3 with an average of 226.1 µg/m^3. In commercial areas (Charbagh, Alambagh, Aminabad and Chowk) the average concentrations of $PM_{2,5}$ were in the range of 304.3 to 390.8 µg/m^3 with an average of 356.9 µg/m^3 respectively. In industrial area (Amausi), the average concentration of $PM_{2.5}$ was 242.0 µg/m^3.

The maximum 24 hours mean concentration of $PM_{2.5}$ was observed in Aliganj (286.5 µg/m^3) residential area and Aminabad (390.8 µg/m^3) in commercial area.

Overall at 24 hrs mean level $PM_{2.5}$ concentration during 3rd phase was found 257.0% higher than the 1st phase.

1.3.3 Sulphur Dioxide (SO_2)

Phase I

In residential areas (Aliganj, Vikas Nagar, Indira Nagar and Gomti Nagar) the mean levels of SO_2 were in the range of 8.7 to 9.7 µg/m^3 with an average of 9.3 µg/m^3. In

commercial areas (Charbagh, Alambagh, Aminabad and Chowk) the average concentrations of SO_2 were in the range of 10.3 to 11.7 µg/m^3 with an average of 11.0 µg/m^3. In industrial area (Amausi), the mean level of SO_2 was 10.7 µg/m^3.

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

Phase III

In residential areas (Aliganj, Vikas Nagar, Indira Nagar and Gomti Nagar) the mean levels of SO_2 were in the range of 9.3 to 17.0 µg/m^3 with an average of 11.9 µg/m^3. In commercial areas (Charbagh, Alambagh, Aminabad and Chowk) the average concentrations of SO_2 were in the range of 10.2 to 18.1 µg/m^3 with an average of 12.5 µg/m^3. In industrial area (Amausi), the mean level of SO_2 was 10.0 µg/m^3.

All the values of SO_2 were well below the prescribed NAAQS of 80 µg/m^3 for all the locations and overall slightly increased (17.1%) in phase III as compared to phase I.

1.3.4 Nitrogen Dioxide (NO_2)

Phase I

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 24.6 to 41.8 µg/m^3 with an average of 32.1 µg/m^3. In commercial areas (Charbagh, Alambagh, Aminabad and Chowk) the average concentrations of NO_2 were found in the range of 29.5 to 40.5 µg/m^3 with an average of 35.0 µg/m^3. In industrial areas (Amausi), the average concentration was 49.7 µg/m^3.

All the values of NO_2 were within the prescribed NAAQS of 80 µg/m^3 for all the monitoring locations.

Phase III

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 48.7 to 108.5 µg/m^3 with an average of 85.6 µg/m^3. In commercial areas (Charbagh, Alambagh, Aminabad

and Chowk) the average concentrations of NO_2 were found in the range of 73.8 to 116.9 µg/m^3 with an average of 95.7 µg/m^3. In industrial areas (Amausi), the average concentration was 63.5 µg/m^3.

The 24 hrs mean values of NO_2 in residential and commercial areas were found to slightly higher than the prescribed NAAQS of 80 µg/m^3. Over all the NO_2 concentration was found to be 147.7% higher in 3rd phase than the 1st phase monitoring value.

Table 8
Concentration (µg/m^3) of PM_{10}, $PM_{2.5}$, SO_2 and NO_2 during Post Monsoon 2019
Phase-I Study: Before Deepawali (1st to 3rd week of October, 2019)

Location	PM_{10} (RSPM)			$PM_{2.5}$			SO_2			NO_2		
Residential												
	Min	**Max**	**Avg**	**Min**	**Max**	**Avg**	**Min**	**Max**	**Avg**	**Min**	**Max**	**Avg**
Aliganj	71.6	238.8	142.9	39.6	122.0	75.2	4.5	18.5	9.6	20.4	59.6	41.8
Vikas Nagar	76.1	296.8	148.1	32.6	112.3	71.1	4.1	13.3	9.1	20.2	67.3	33.1
Indira Nagar	93.2	228.4	159.5	42.7	123.3	77.3	3.8	15.1	8.7	22.5	40.3	29.1
Gomti Nagar	99.4	255.7	165.4	73.2	107.8	93.6	4.9	14.6	9.7	17.1	39.5	24.6
Commercial												
Charbagh	124.3	313.3	197.4	48.2	199.0	109.6	6.0	22.0	11.5	26.5	67.6	40.0
Alambagh	114.9	297.1	157.4	47.4	118.3	70.8	4.4	21.9	10.4	28.2	60.6	40.5
Aminabad	63.8	269.6	168.3	32.0	103.1	66.5	3.1	22.7	11.7	21.5	41.0	30.1
Chowk	77.0	250.9	138.6	47.7	141.2	76.8	3.4	21.9	10.3	21.6	45.4	29.5
Industrial												
Amausi	76.4	246.5	153.7	42.5	138.6	80.1	3.7	19.7	10.7	20.6	85.6	49.7
NAAQS	100			60			80			80		
WHO Guidelines	50			25			20			40*		

Number of Observations=6, *= Annual Average, NAAQS=National Ambient Air Quality Standard

Table 9

Concentration (µg/m^3) of PM_{10}, $PM_{2.5}$, SO_2 and NO_2 during Post Monsoon 2019

Part-III Study: After Deepawali (1st and 4th November, 2019)

Location	PM_{10} (RSPM)			$PM_{2.5}$			SO_2			NO_2		
	1st	4th	Avg	1st	4th	Avg	1st	4th	Avg	1st	4th	Avg
Residential												
Aliganj	476.9	516.3	496.6	243.2	329.9	286.5	5.8	12.8	9.3	57.2	40.3	48.7
Vikas Nagar	475.3	440.6	457.9	232.0	178.9	205.4	12.6	11.2	11.9	148.6	44.9	96.7
Indira Nagar	404.7	367.9	386.3	194.4	174.1	184.2	23.6	10.4	17.0	113.6	63.3	88.4
Gomti Nagar	432.4	416.7	424.5	274.1	181.8	227.9	8.2	10.8	9.5	125.8	91.3	108.5
Commercial												
Charbagh	508.0	518.4	513.2	298.2	310.5	304.3	18.2	17.9	18.1	80.3	67.3	73.8
Alambagh	498.0	445.4	471.7	364.4	355.9	360.1	6.9	13.5	10.2	104.1	61.7	82.9
Aminabad	437.2	579.8	508.5	381.3	400.4	390.8	11.8	10.2	10.6	184.8	49.0	116.9
Chowk	460.3	551.4	505.8	343.3	401.8	372.5	11.1	10.3	10.7	164.9	53.4	109.1
Industrial												
Amausi	426.3	424.2	425.2	321.4	162.7	242.0	9.4	10.6	10.0	85.5	41.6	63.5
NAAQS	100			60			80			80		
WHO Guidelines	50			25			20			40*		

Number of Observations= 2 *= Annual Average, NAAQS=National Ambient Air Quality Standard

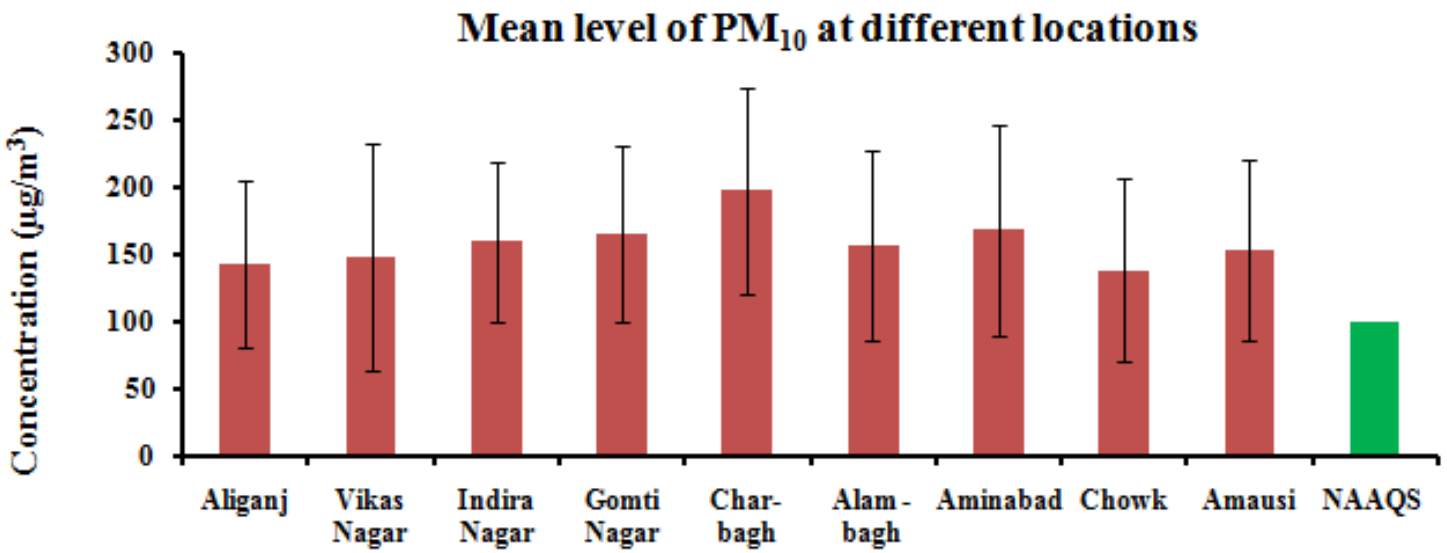


Figure 2A: Concentration (µg/m^3) of PM_{10}, in different areas of Lucknow city during Pre Monsoon Season (October, 2019) compared with prescribed National Ambient Air Quality Standard (NAAQS)
Each bar represents mean ± SD of 6 values

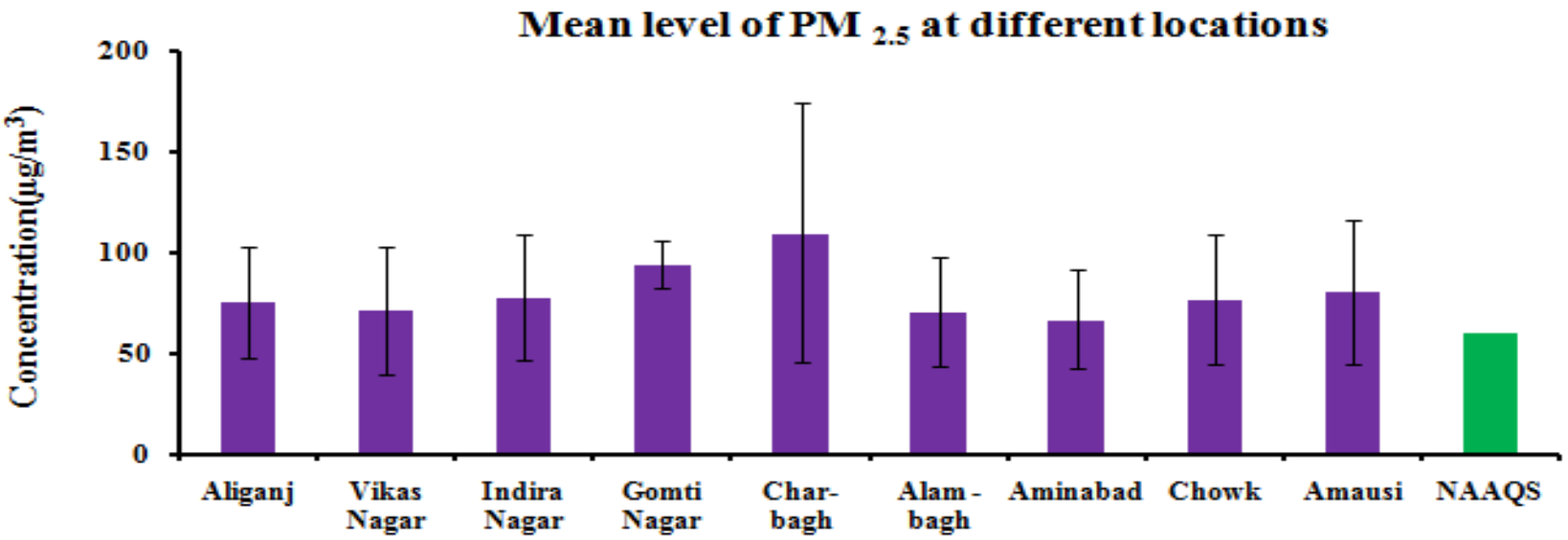


Figure 2B: Concentration (µg/m^3) of $PM_{2.5}$ in different areas of Lucknow city during Pre Monsoon Season (October, 2019) compared with prescribed National Ambient Air Quality Standard (NAAQS)
Each bar represents mean ± SD of 6 values

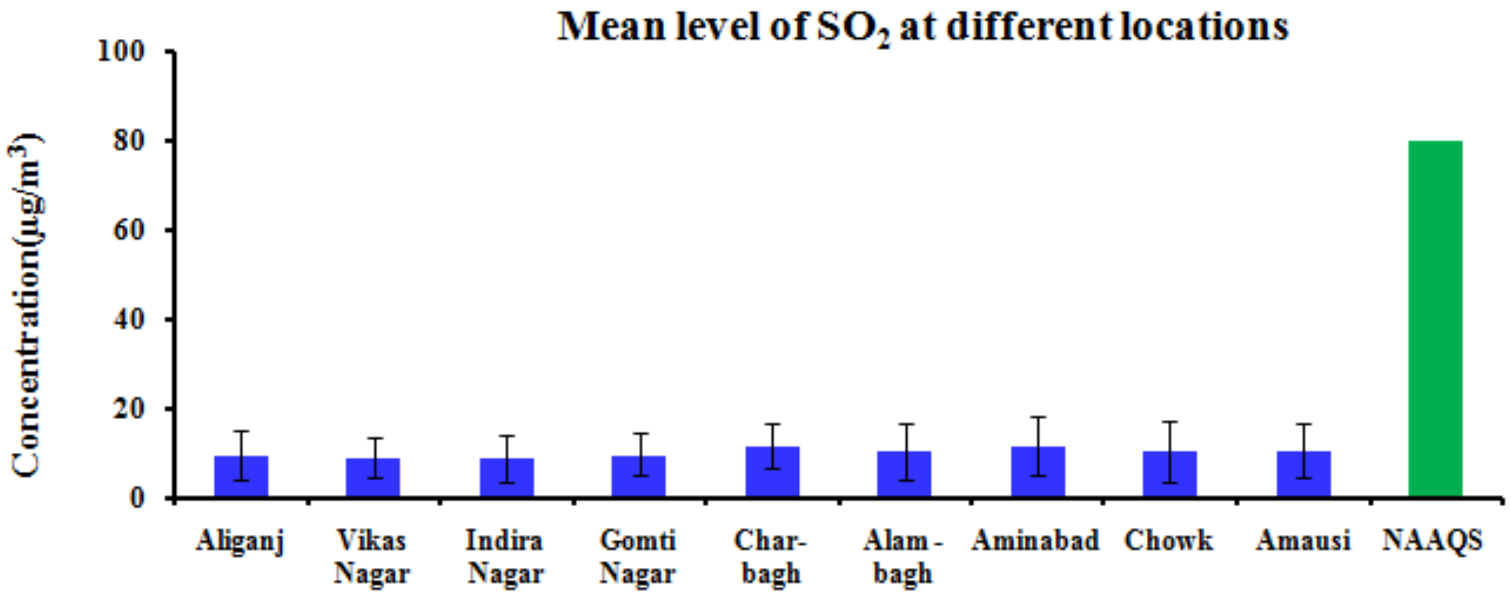


Figure 2C: Concentration (µg/m^3) of SO_2 in different areas of Lucknow city during Pre Monsoon Season (October, 2019) compared with prescribed National Ambient Air Quality Standard (NAAQS)
Each bar represents mean ± SD of 6 values

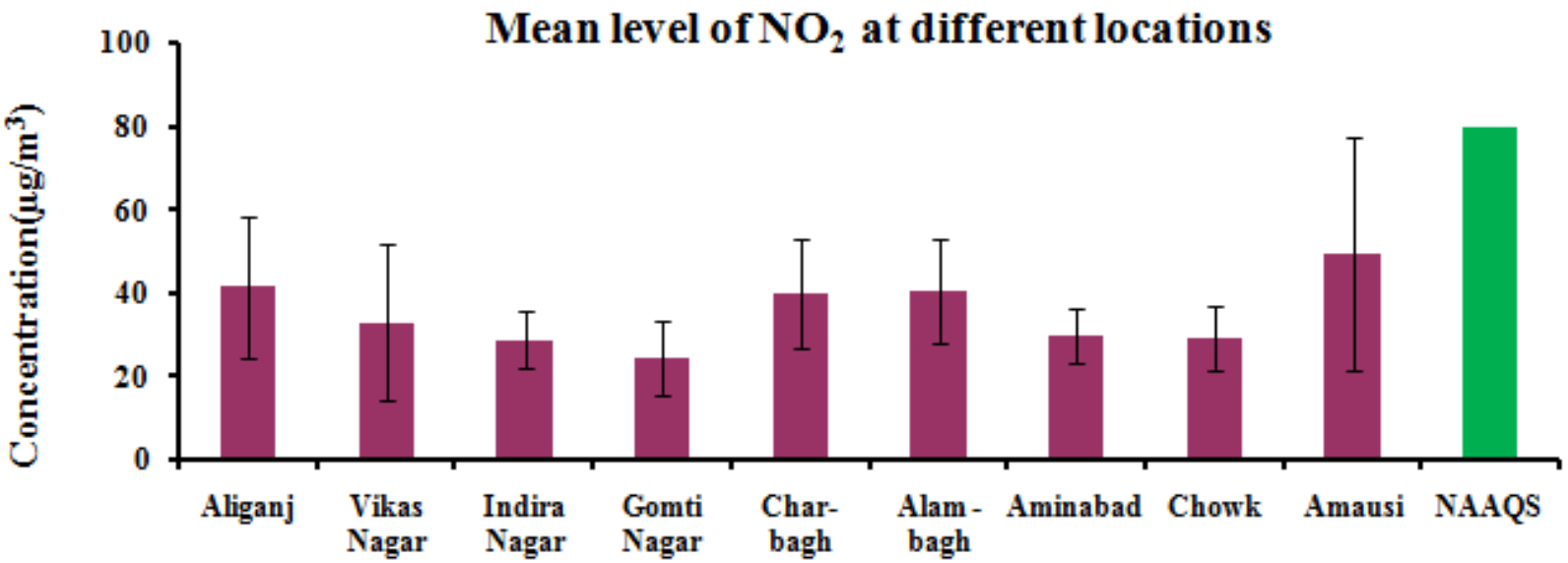


Figure 2D: Concentration (µg/m^3) of NO_2 in different areas of Lucknow city during Pre Monsoon Season (October, 2019) compared with prescribed National Ambient Air Quality Standard (NAAQS)
Each bar represents mean ± SD of 6 values

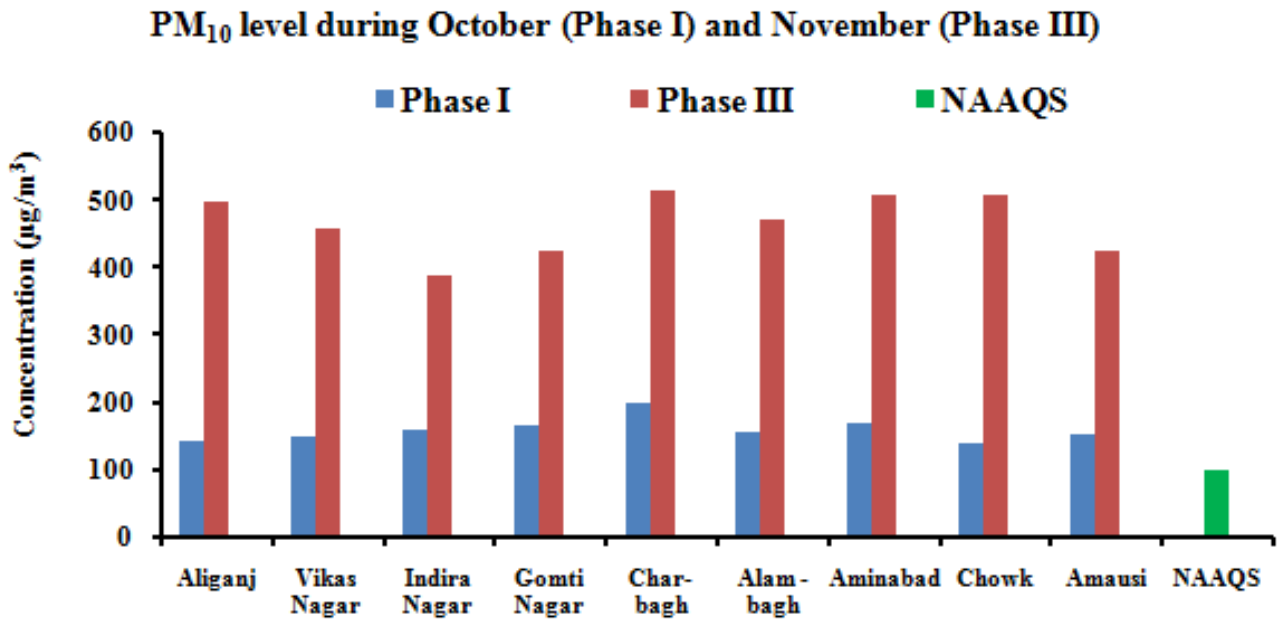


Figure 3A: Comparison of PM_{10} concentration ($\mu g/m^3$) in different areas of Lucknow city during phase I (October, 2019) and phase III (November 2019) compared with prescribed National Ambient Air Quality Standard (NAAQS)
No of observations for phase I= 6, for phase III=2

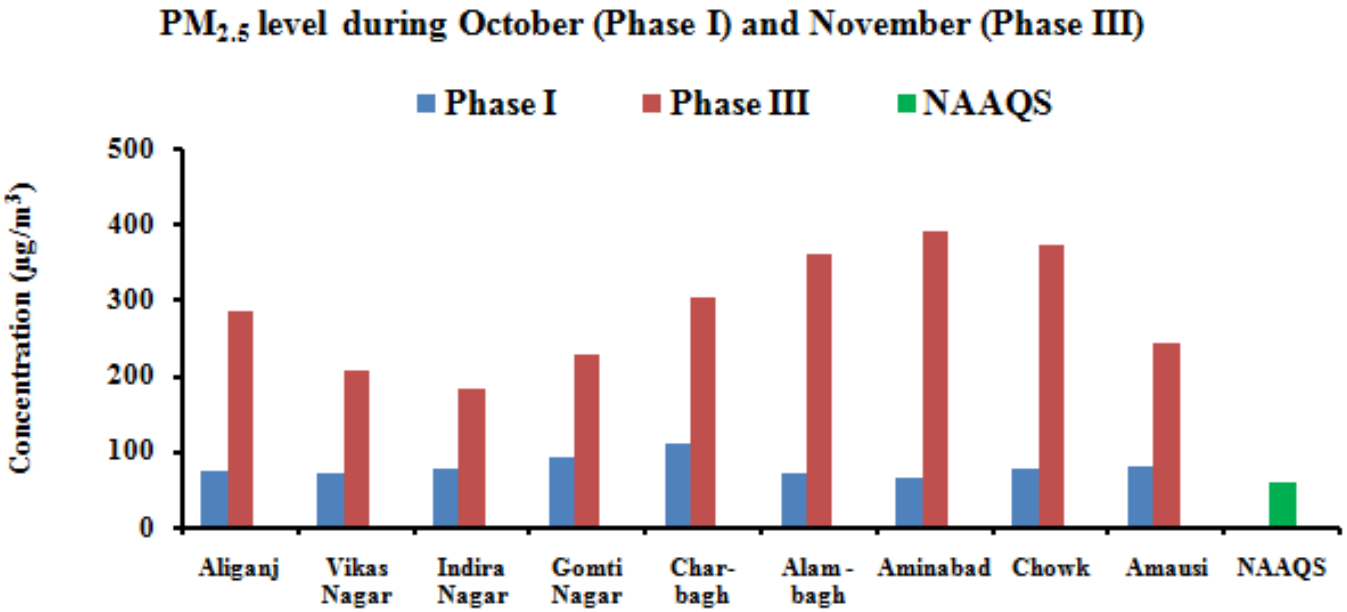


Figure 3B: Comparison of $PM_{2.5}$ concentration ($\mu g/m^3$) in different areas of Lucknow city during phase I (October, 2019) and phase III (November 2019) compared with prescribed National Ambient Air Quality Standard (NAAQS)
No of observations for phase I= 6, for phase III=2

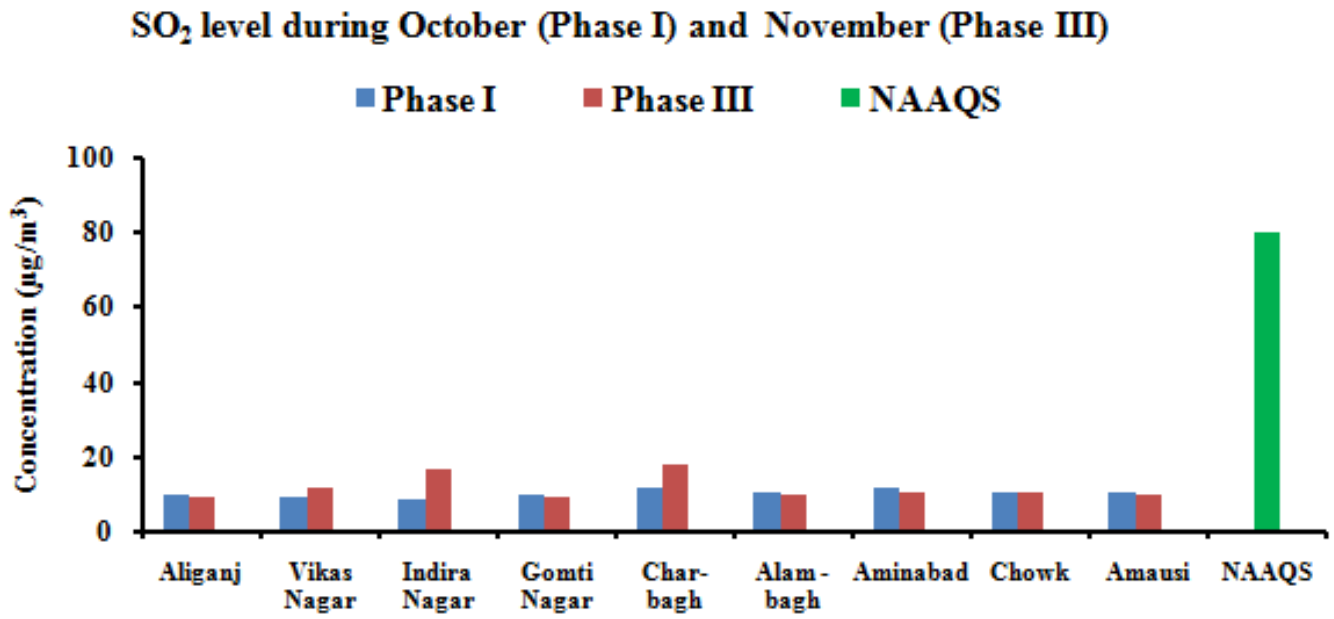


Figure 3C: Comparison of SO_2 concentration ($\mu g/m^3$) in different areas of Lucknow city during phase I (October, 2019) and phase III (November 2019) compared with prescribed National Ambient Air Quality Standard (NAAQS)
No of observations for phase I= 6, for phase III=2

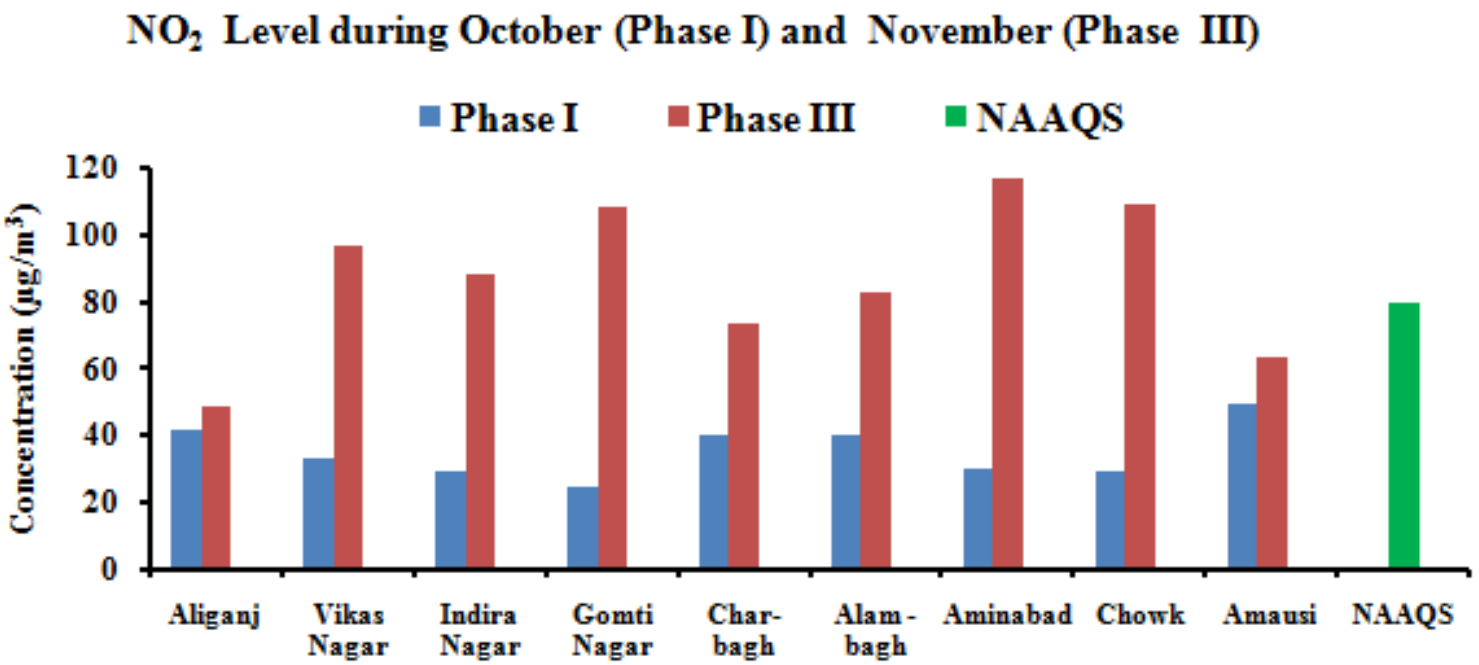


Figure 3D: Comparison of NO_2 concentration ($\mu g/m^3$) in different areas of Lucknow city during phase I (October, 2019) and phase III (November 2019) compared with prescribed National Ambient Air Quality Standard (NAAQS)
No of observations for phaseI1= 6, for phase III=2

1.3.5 Trace Elements in Ambient Air (RSPM)

The trace elements (Pb, Ni, Cd, Cu, Zn, Co, Mn, Fe, Ca, Mg, Na and K) were estimated in ambient air associated with PM_{10} at nine monitoring locations. The results are presented in Table 10. The 24 hr mean concentration of metals were found to be Pb=47.12 (24.75-94.90) and Ni=14.50 (4.06-37.40) ng/m^3, Cd=3.32 (2.47-4.19), Cu=9.04 (5.43-16.32), Zn=130.28 (73.30-168.03), Co=3.41 (0.77-14.65), Mn=20.58 (10.91-41.94), Fe=494.54 (285.88-875.23), Ca=2682.38 (1562.8-5483.40), Mg=486.24 (324.69-1125.27), Na=18962.32 (15754.74-29416.44) and K=739.57 (564.18-1099.18) ng/m^3.

The 12 trace elements in PM_{10}, were monitored on 2nd week of October (9th October, 2019) and their mean level of all the nine locations were found to be in the following ascending order-

Cd <Co <Cu <Ni <Mn <Pb <Zn <Mg <Fe <K <Na <Ca

Table 10

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

S. No.	Location	Pb	Ni	Cd	Cu	Zn	Co	Mn	Fe	Ca	Mg	Na	K
Residential													
1	Aliganj	33.41	4.06	3.16	5.43	140.50	1.51	14.25	285.88	2272.59	335.93	19017.76	648.39
2	Vikas Nagar	29.00	30.26	2.84	5.69	113.94	3.01	41.94	293.83	2029.17	325.84	18537.69	578.21
3	Indira Nagar	94.91	5.84	4.10	7.66	168.03	3.16	14.56	446.07	2240.30	389.04	21065.83	855.58
4	Gomti Nagar	24.75	37.40	2.91	5.79	97.81	2.78	10.91	369.55	1562.80	324.69	15985.19	564.18
Commercial													
5	Charbagh	34.58	16.17	2.47	10.80	136.78	0.77	21.54	612.21	5483.40	586.19	15754.74	769.76
6	Alambagh	40.75	6.61	3.67	14.53	73.30	14.65	33.54	875.23	2091.84	1125.27	29416.44	750.84
7	Aminabad	83.80	14.42	4.19	9.13	158.49	1.00	17.45	654.05	3196.80	426.36	18118.19	1099.18
8	Chowk	51.71	11.71	3.79	16.32	135.15	1.53	13.58	400.88	2868.46	430.74	16201.72	799.64
Industrial													
9	Amausi	31.17	4.70	2.74	6.01	148.56	2.24	17.45	513.14	2396.61	432.14	16563.33	590.38
Mean		**47.12**	**14.57**	**3.32**	**9.04**	**130.28**	**3.41**	**20.58**	**494.54**	**2682.44**	**486.24**	**18962.32**	**739.57**
NAAQS		1000	20*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Number of Observations = 1(Each value is representative of 24 hour monitoring)

*=Annual Average, NS = Not Specified

1.3.6 Noise Level

The noise monitoring data recorded during the post monsoon period (October, 2019) is presented in Table 11. In residential areas, the day and night time noise levels were recorded between 65.9 to 69.5 and 58.9 to 64.8 dB(A) respectively. All the values were higher than the prescribed limits of 55 and 45 dB(A) for day and night time respectively. In commercial and traffic area, the day and night time noise levels were recorded between 68.9 to 77.2 and 58.0 to 68.9 dB(A) respectively. Noise levels at all the commercial sites during day and night time were found above the prescribed limits of 65 and 55 dB(A) respectively. In industrial area, Amausi, the day and night time noise levels were recorded as 71.9 and 68.8 dB(A) respectively. Noise levels at industrial area during day time and night time were recorded lower than the prescribed limits of 75.0 and 70.0 dB(A) respectively. There is no major industrial activity in this area and the major source of noise is transport.

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

S. No.	Area	Location	Time	Noise level dB(A)
1	**Residential**	Aliganj	Day (02:00 pm - 03:00 pm)	69.5
			Night (11:30 pm - 12:30 am)	62.8
		Vikas Nagar	Day (04:00 pm - 05:00 pm)	65.9
			Night (10:30 pm - 11:30 pm)	58.9
		Indira Nagar	Day (03:00 pm - 04:00 pm)	67.4
			Night (11:30 pm - 12:30 am)	64.8
		Gomti Nagar	Day (03:00 pm - 04:00 pm)	68.7
			Night (12:00 am - 01:00 am)	60.1
		Standards	**Day**	**55**
			Night	**45**
2	**Commercial**	Charbagh	Day (03:00 pm - 04:00 pm)	77.2
			Night (11:30 pm - 12:30 am)	68.9
		Alambagh	Day (02:40 pm - 03:40 pm)	68.7
			Night (01:00 am - 02:00 am)	62.8
		Aminabad	Day (03:00 pm - 04:00 pm)	76.3
			Night (03:50 am - 04:50 am)	58.0
		Chowk (sensitive)	Day (03:00 pm - 04:00 pm)	73.7
			Night (10:30 pm - 11:30 pm)	66.8
		Standards	**Day**	**55**
			Night	**65**
3	**Industrial**	Amausi	Day (03:00 pm - 04:00 pm)	71.9
			Night (01:30 am - 02:30 am)	68.8
		Standards	**Day**	**75**
			Night	**70**

One time and one hour observation

1.4 TRENDS OF AMBIENT AIR QUALITY IN LUCKNOW CITY

The observed PM_{10}, $PM_{2.5}$, SO_2 and NO_2 for 5 years data have been compared to find out the prevailing trend of air pollution in Lucknow city (Figures 4-7). A slight change in the values may be attributed to some local environmental and climatic factors.

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

The level of PM_{10} at all the residential, commercial and industrial areas was found to be lower when compared to the data of the previous year. All the values are higher than the NAAQS (Figure 4).

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

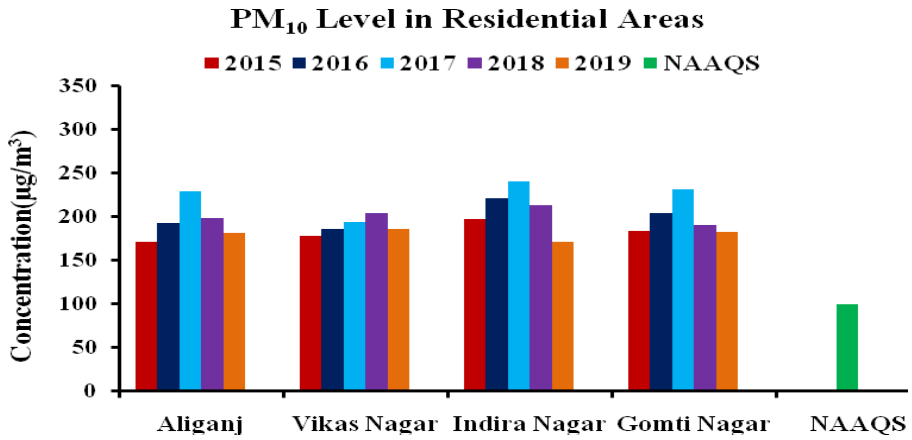
The level of $PM_{2.5}$ has been compared with last four year data and all the values of residential, commercial and industrial areas were found to be lower than the previous years. All the values of the present study were found to be higher than the NAAQS (Figure 5).

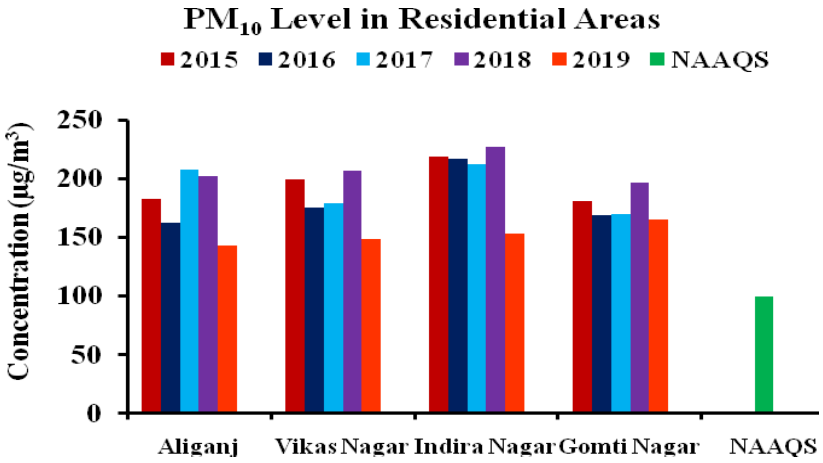
1.4.3 Sulphur dioxide (SO_2)

The level of SO_2 during pre monsoon since 2015 is presented in Figure 5 for all the locations. In residential, commercial and industrial areas, lower concentration of SO_2 was found at all locations except Charbagh compared to that of the previous year. All the values of the present study were found to be lower than the NAAQS (Figure 6).

1.4.4 Oxides of Nitrogen (NO_2)

The level of NO_2 during pre monsoon since 2015 is presented in Figure 5 for all the locations. All the residential areas showed lower values except Aliganj and Gomti nagar. All the commercial and one industrial locations, showed lower value when compared with the previous year data. All the values of the present study were found to be lower than the NAAQS (Figure 7).





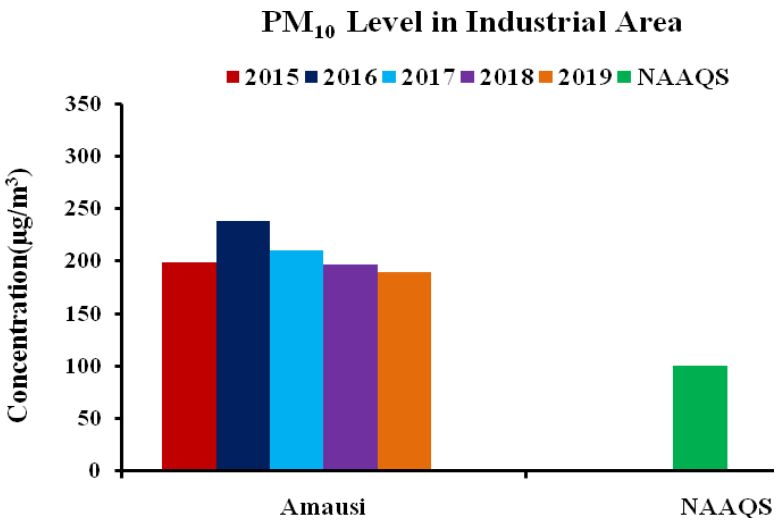


Figure 4: Concentration (µg/m^3) of PM_{10} (RSPM) in Residential, Commercial and Industrial areas of Lucknow city during 2015 to 2019 and compared with prescribed National Ambient Air Quality Standard (NAAQS)

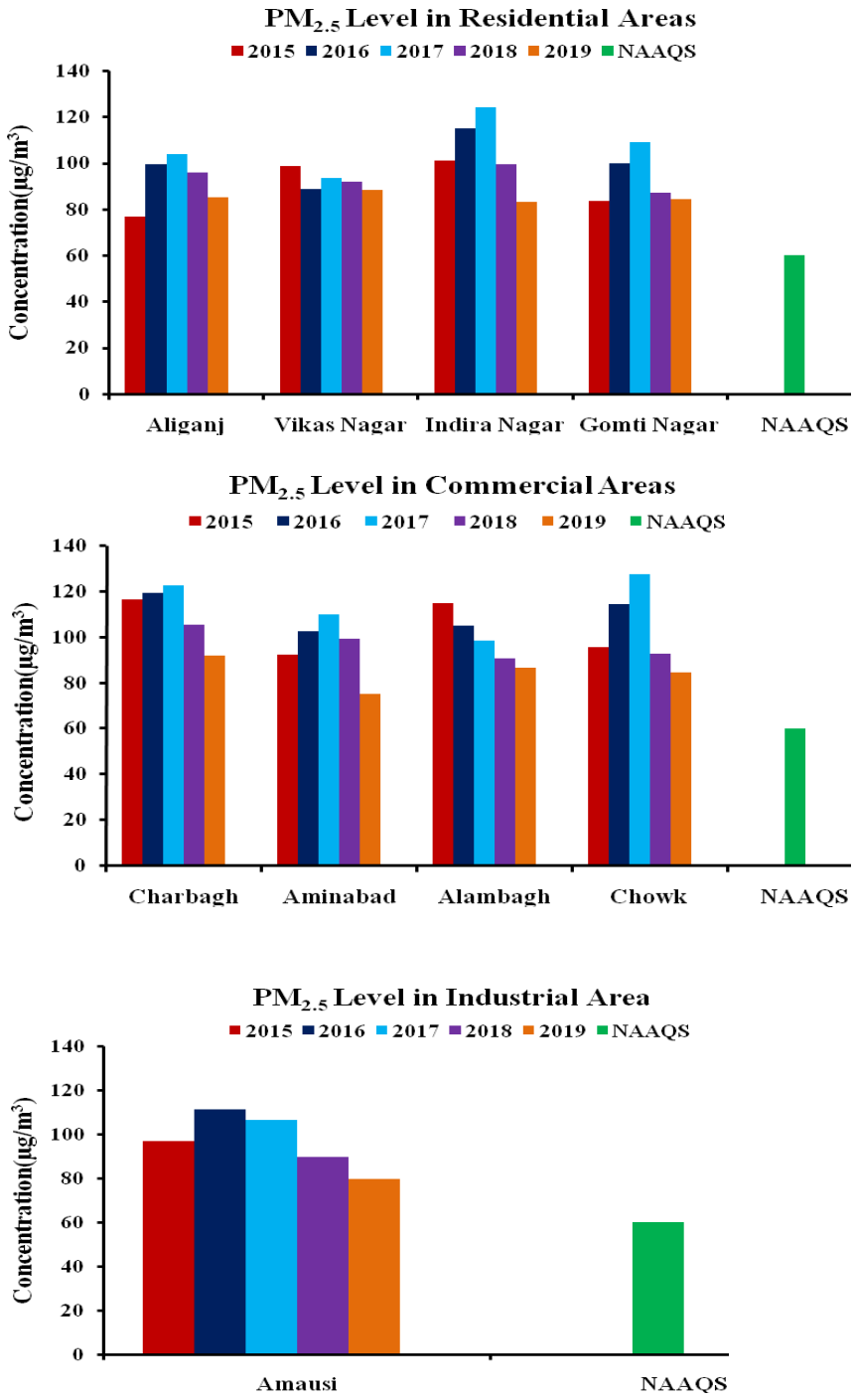


Figure 5: Concentration (µg/m^3) of $PM_{2.5}$ in Residential, Commercial and Industrial areas of Lucknow city during 2015 to 2019 and compared with prescribed National Ambient Air Quality Standard (NAAQS)

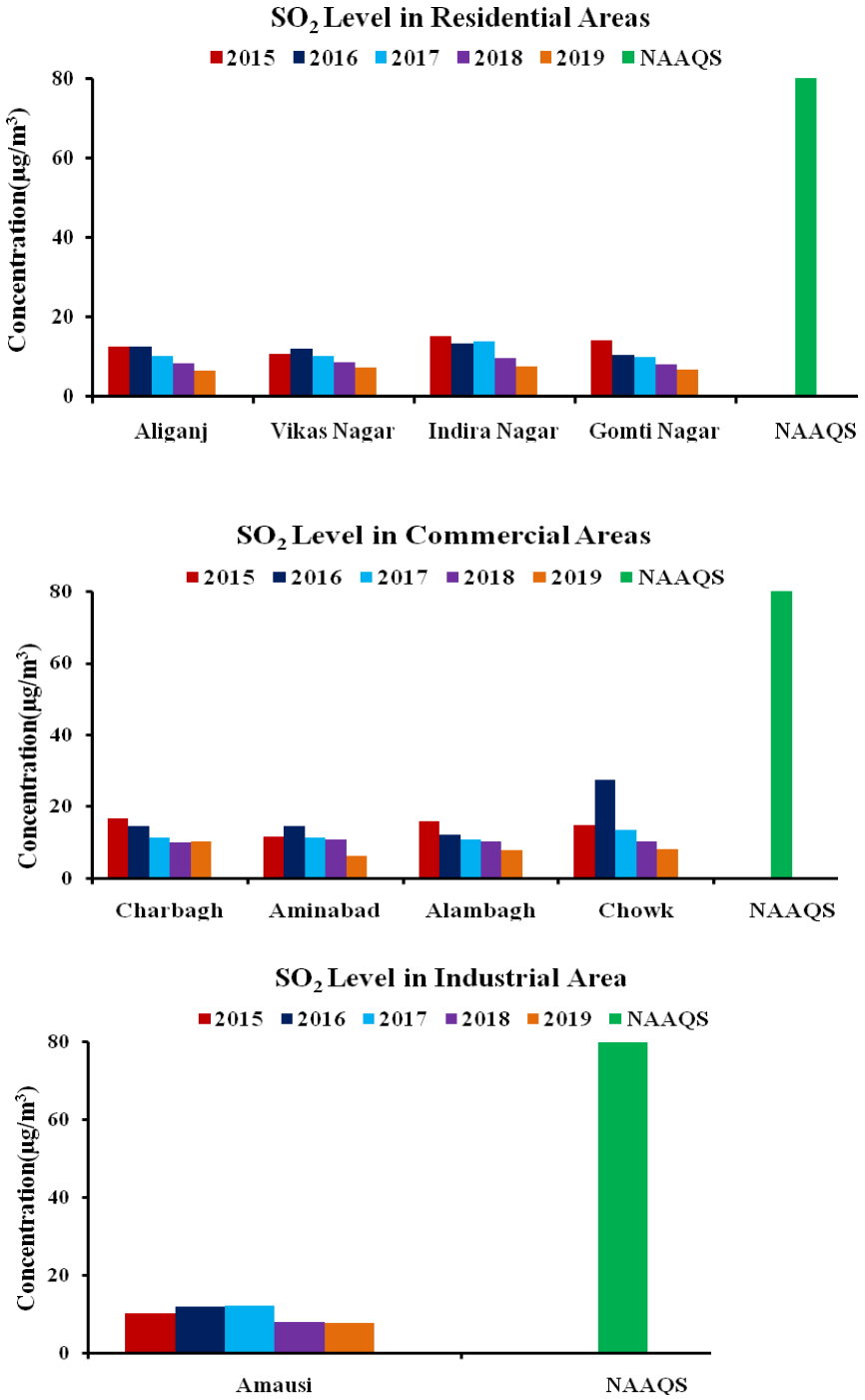


Figure 6: Concentration (µg/m^3) of SO_2 in Residential, Commercial and Industrial areas of Lucknow city during 2015 to 2019 and compared with prescribed National Ambient Air Quality Standard (NAAQS)

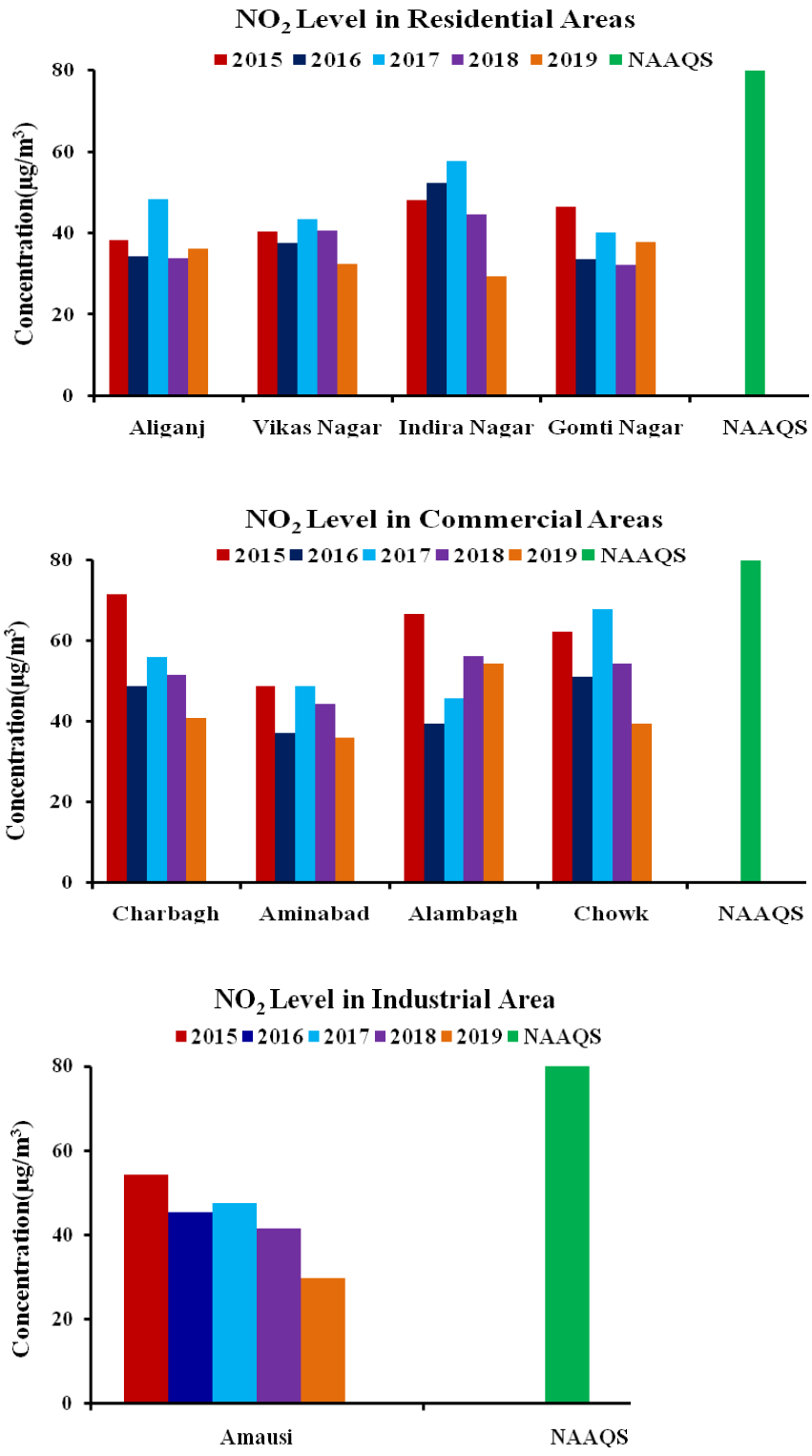


Figure 7: Concentration (µg/m^3) of NO_2 in Residential, Commercial and Industrial areas of Lucknow city during 2015 to 2019 and compared with prescribed National Ambient Air Quality Standard (NAAQS)

1.4.5 Trace elements

Lead (Pb)

The level of Pb during post monsoon since 2015 is presented in Figure 8 for all the locations. The values showed a decreasing trend at all the residential areas, commercial areas and also in industrial area except Indira Nagar and Alambagh.

Nickel (Ni)

The level of Ni during post monsoon since 2015 is presented in Figure 9 for all the locations. The values showed a decreasing trend at all the residential areas except Vikas nagar and Gomti nagar. In commercial areas higher values were found in Aminabad and Chowk and industrial area showed decreasing trend.

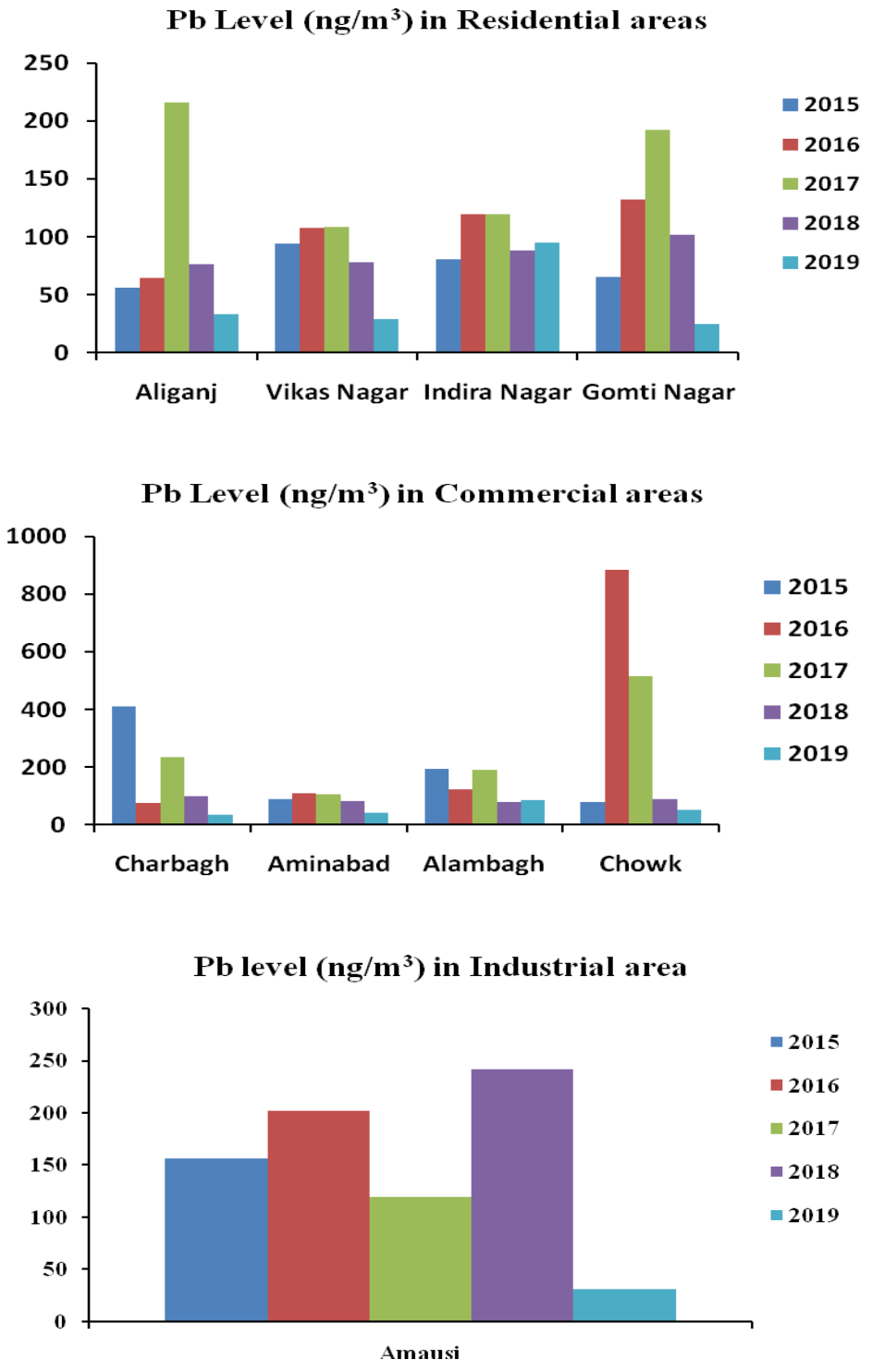


Figure 8: Concentration (ng/m^3) of Lead (Pb) in Residential, Commercial and Industrial areas of Lucknow city during 2015 to 2019.

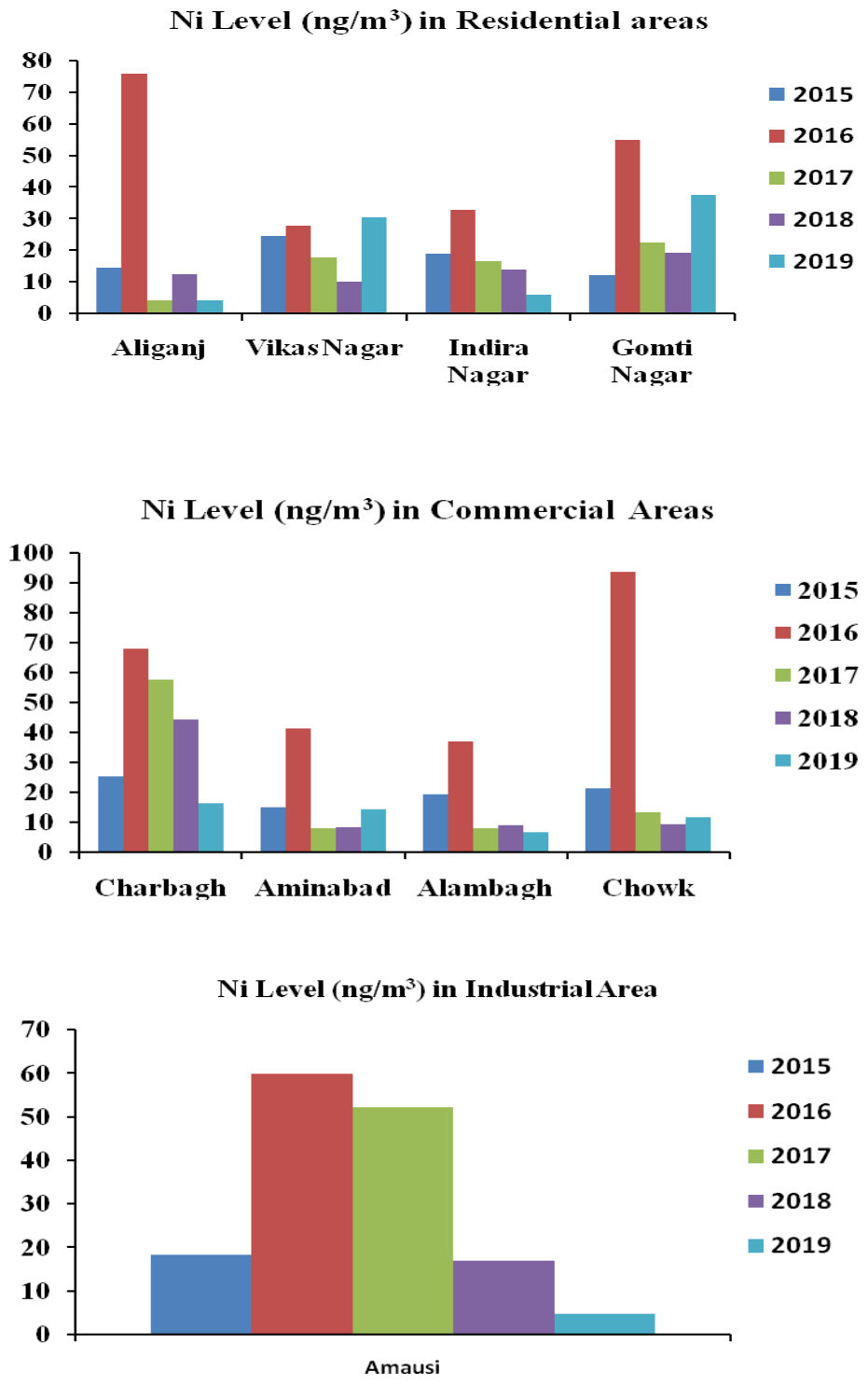


Figure 9: Concentration (ng/m^3) of Nickel (Ni) in Residential, Commercial and Industrial areas of Lucknow city during 2015 to 2019.

1.4.6 Noise Level

Current year's noise data was compared with the corresponding data of the previous four years (2015 to 2019) and presented in Figure 10 and 11. The comparative noise levels in residential, commercial and industrial areas are described below:

Day time Noise Level

In residential areas, all the locations showed slightly decreasing trend over that of the previous year. In commercial cum traffic areas, also noise level was found to be on the lower side except Chowk, when compared to that of previous year. In industrial area (Amausi) too noise level was slightly lower than that of the previous year. The comparative data are presented in Figure 10.

Night time Noise Level

Residential areas showed slightly higher level than that of the last year. In commercial areas, noise was recorded on the lower side at all locations except Alambagh and the only industrial area showed slightly lower value than that of the previous year. The comparative data are presented in Figure 11.

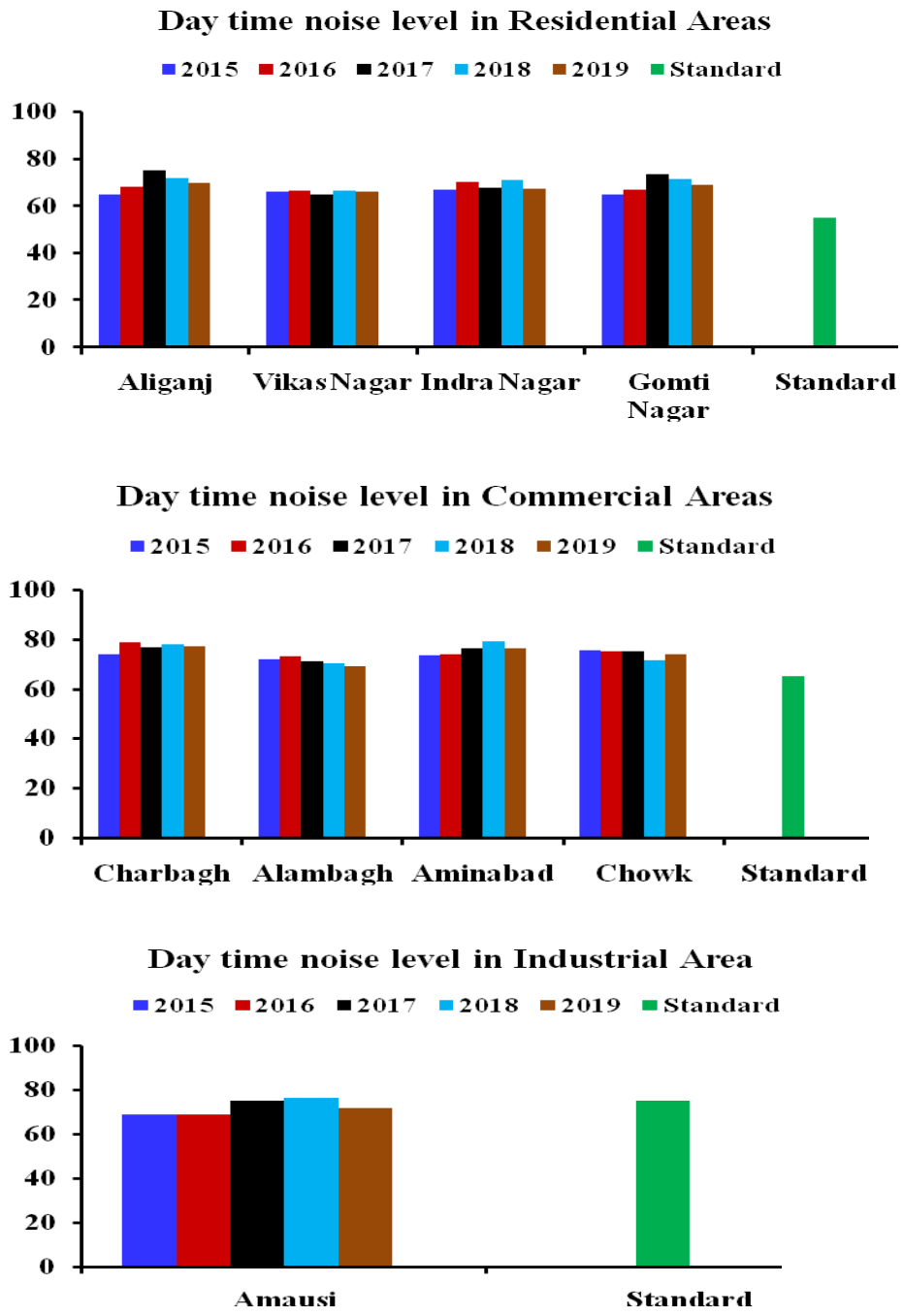


Figure 10: Comparison of day time Noise Level dB(A) in different areas of Lucknow city (2015-2019)

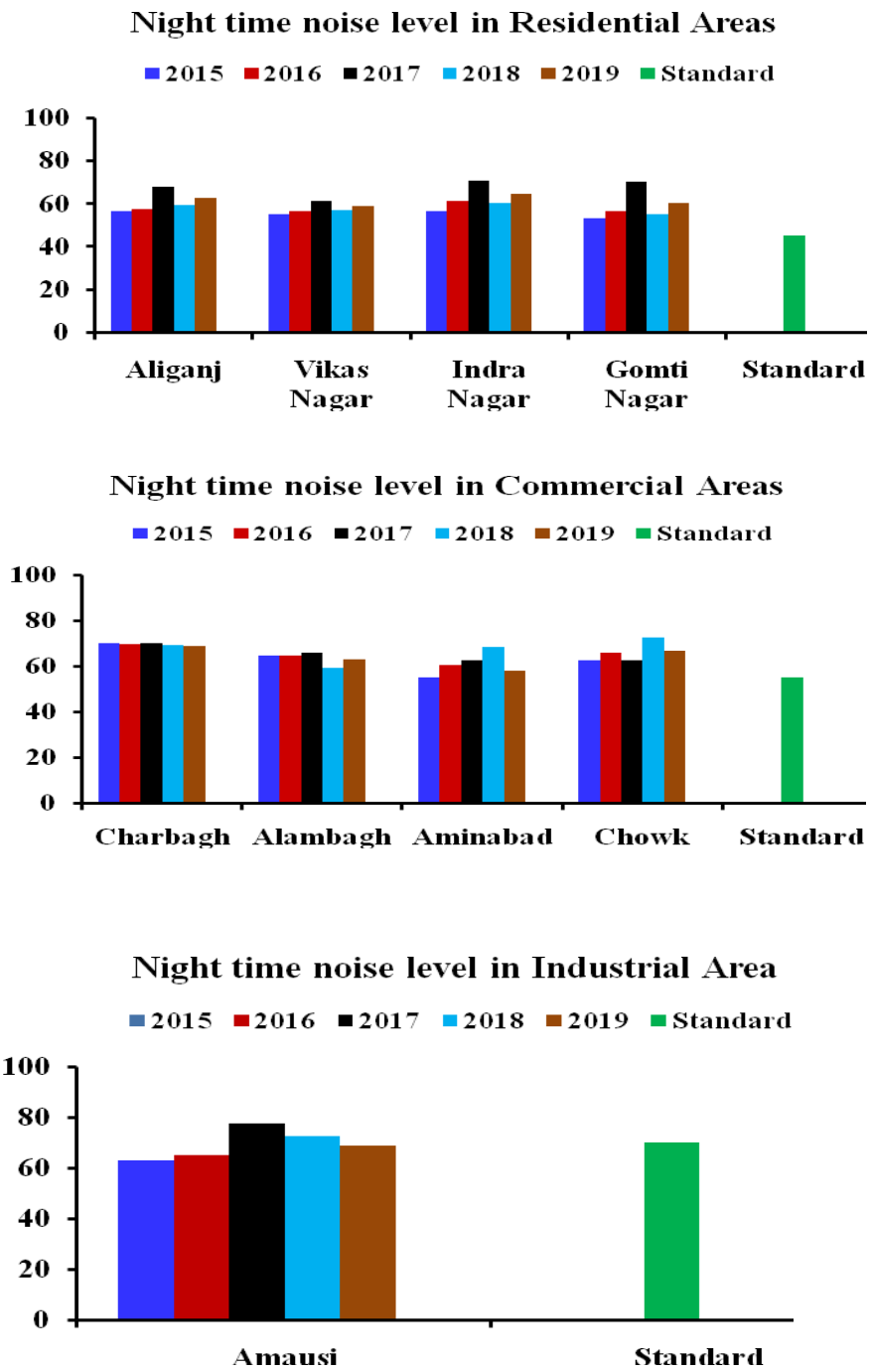


Figure 11: Comparison of night time Noise Level dB(A) in different areas of Lucknow city (2015-2019)

1.5 HEALTH EFFECTS

The concentration of air pollutants usually remains higher than the NAAQS-2009 limits in India throughout the winter season. The common indicator of air pollution level; AQI also recorded as Poor (201-300), Very Poor (301-400) and Severe (>400) in various cities during winter. Exposure to higher levels of air pollutants has adverse health effects on human being and environment. Air Pollution may be the cause of significant health problems that include premature death, aggravated asthma, acute respiratory symptoms, and decreased lung function in the form of shortness of breath and chronic bronchitis etc. Further fine particles can remain suspended in the air and travel long distances across regional and international borders without sinking and settling. It is also responsible for visibility problem and global warming. A number of epidemiological studies have reported that the increase in particulate matter concentration is responsible for increased morbidity and mortality.

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

An increase in the mortality and morbidity has been reported in the people exposed to higher PM_{10} and $PM_{2.5}$ levels. The degree of effect depends on the physicochemical properties of the PMs which depend on the level of associated trace elements, organic chemicals as well as the other pollutants. Overall, the effects/toxicity depends on the synergistic effects of physicochemical properties of PM, the levels of various organic and inorganic elements attached with it and environmental circumstances including receptors conditions.

Elevated levels of noise have adverse effects varying from hearing loss to annoyance. Annoyance and psychological damage would occur at much lower noise levels. Air pollutants and noise pollution effect on human health is given below:

1.5.1 Particulate Matter (PM_{10} & $PM_{2.5}$)

- Fine air born particulate matter (diameter ≤ 2.5 µm) would penetrate beyond the larynx on inhalation.
- Small particles penetrate deep into the lung and can cause respiratory disease such as emphysema and bronchitis, and aggravate existing heart disease.
- Ultra fine particles ranging from 0.001 to 0.1 micron in diameter are able to penetrate deep into the lungs and to the alveolar sacs where gaseous exchange occurs.
- Further these particles increase the rates of blood flow and vascular permeability to white blood cells, elevating clotting activity, constriction of the airways and fever induction.

1.5.2 Sulfur Dioxide (SO_2)

- Increased ambient air SO_2 may cause irritation of the eyes, nose and throat, choking and coughing.
- Reflex cough, irritation, and a feeling of chest tightness, which may lead to narrowing of the airways is particularly likely to occur in people suffering from asthma and chronic lung disease, whose airways are often inflamed and easily irritated.
- Oral inhalation of larger volumes may reach the segmental bronchi and damage the organ and exposure of the eyes (eg. in an industrial accident) can cause severe burns often resulting in the loss of vision.
- Repeated or prolonged exposure to moderate concentrations may cause inflammation of the respiratory tract, wheezing and lung damage other health effects include headache, general discomfort and anxiety.

1.5.3 Oxides of Nitrogen (NO_2)

- NO_2 causes a wide variety of health and environmental impacts because of various compounds and derivatives in the family of NOx including NO_2, HNO_3, NO, nitrates and nitric oxide.
- Nitrogen dioxide (NO_2) is associated with mortality and a range of morbidity outcomes.
- NO_2 can be used as a marker of traffic proximity and convenient metric for modelling the health impacts of traffic pollution and evaluating abatement policies.
- Long term exposure to NO_2 may affect lung function and lower the resistance to diseases such as pneumonia and influenza.
- Extremely high-dose exposure (as in a building fire) to NO_2 may result in pulmonary edema, diffuse lung injury and development of acute or chronic bronchitis.
- Industrial exposures to nitric oxide can cause unconsciousness, vomiting, mental confusion, and damage to the teeth.
- Exposure to low levels of nitrogen oxides in smog can irritate the eyes, nose, throat and lungs and can cause coughing, shortness of breath, fatigue, and nausea.

1.5.4 Trace elements

Lead (Pb)

- Lead is neuro-toxic. Impairment of neurodevelopment in children, affects the development of brain of the foetus.
- Mortality in workers exposed to high level of lead is increased.
- Decreased nerve conduction velocity, cognitive development and instinctual performance, hearing loss, jaundice, anemia in children.
- Cognitive and neurobehavioural deficits in children at low levels of exposure are of great concern.

Nickel (Ni)

- The harmful human health effect of nickel is an allergic reactions, chronic bronchitis, reduced lung function, lung cancer and nasal sinus cancer.

- Animal studies have found increase in newborn deaths and decrease in newborn weight after ingesting Nickel.

Cadmium (Cd)

- The human health effect of cadmium on the kidney, the skeletal system and the respiratory system. Cd affects the calcium metabolism, lead to the formation of kidney stones, itai-itai disease, osteomalacia, osteoporosis, painful bone fractures and kidney dysfunction due to Cd exposure. Cd is a known carcinogenic.

1.5.5 Noise Pollution

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

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 (CPCB, 2009), but there are several reports suggesting that gaseous pollutants are related with respiratory diseases and reproductive and developmental effect even at low concentrations. Vehicular traffic and NO_2 are associated with significantly higher risk of lung cancer.

1.6 CONCLUSIONS

During Post monsoon (October-November), 2019 air pollutants such as PM_{10}, $PM_{2.5}$, SO_2, NO_2 and trace elements including Pb and Ni were monitored for the assessment of ambient air quality. Besides, noise level was also monitored during day and night time at 9 locations. Results are presented in three parts- phase I - before Deepawali, phase II Deepawali and after Deepawali i.e phase III. The results revealed the following:

- The concentration of PM_{10}, $PM_{2.5}$, SO_2 and NO_2 of post monsoon phase I of the study were found lower over the previous year by 25.2, 23.9, 2.9 and 29.9% respectively.

- The mean RSPM (PM_{10}) levels at all the residential, commercial and industrial monitoring locations were higher than the NAAQS.

- The mean level of FPM ($PM_{2.5}$) at all the monitoring locations was higher than the NAAQS.

- The concentrations of gaseous pollutants, SO_2 and NO_2 were below the prescribed NAAQS (80 $\mu g/m^3$) at all the locations but comparatively showed slightly lower values compared to previous year during phase I study.

- Comparatively, the concentration of PM_{10}, $PM_{2.5}$, SO_2 and NO_2 were found much higher during 3rd phase of our study, which were 194% for PM_{10}, 257% for $PM_{2.5}$, 17.1% for SO_2 and 147.7% for NO_2 over the phase-I values. In general air quality depends on several factors and among them are meteorological parameters like wind speed, wind direction, temperature, relative humidity etc. During the phase-I study, pollution levels were comparatively lower than the previous years, which might be attributed to extended rainfall till September end. Pollution level was found to follow a gradually increasing trend with time during the study period. The increasing trend might be due to change of weather conditions like downward trend of ambient temperature, increase of relative humidity and more calm condition (low wind speed). The prevailing atmospheric conditions were not suitable to disperse, dilute and transport the air pollutants.

- During Deepawali night pollution levels increased over pre Deepawali night. For PM_{10} it was 129% (234.1 to 536.5 µg/m^3), for $PM_{2.5}$ it was 117.6% (159.2 to 236.6 µg/m^3), for SO_2 it was 175% (12.9 to 35.7 µg/m^3) and NO_2 was 218% (31.6 to 100.7 µg/m^3). The short term change of pollution level was due to fireworks and prevailing weather condition. The short-term high levels of air pollutants have severe impact on human health and other living beings.

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

- Overall results of post monsoon phase I indicate that all the parameters monitored showed slightly decreasing trend in comparison to last year which might be due to full-fledged operation of metro rails, cleanliness of roadside areas, restriction of municipal solid waste burning and prevailing meteorological conditions. As per recommendations made in our previous reports district administration has taken measures to minimize air pollution which also helped to improve the air quality of the city.

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

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

1.7 RECOMMENDATIONS FOR MITIGATION OF AIR POLLUTION

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

Acknowledgements

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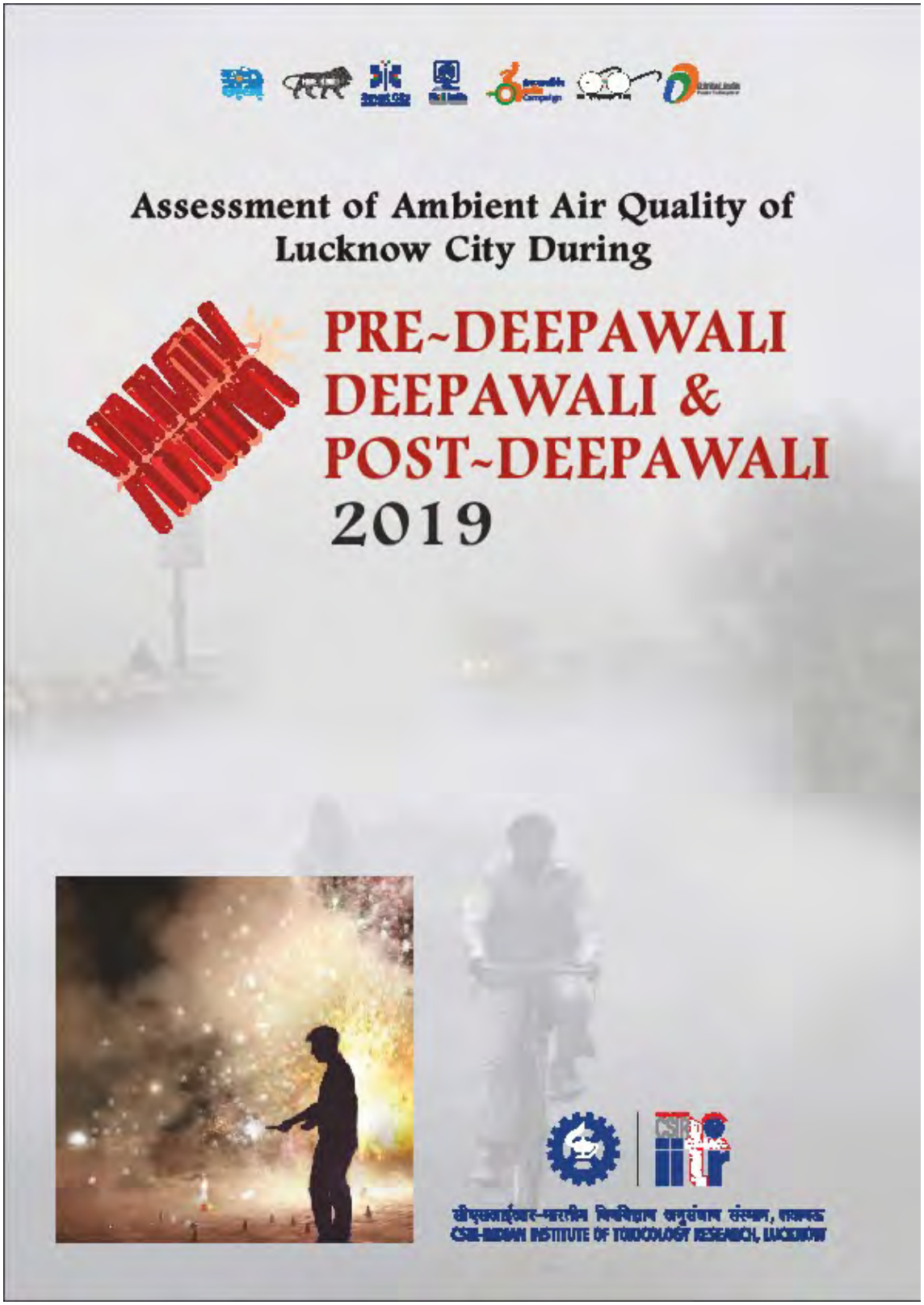
ANNEXURE-1: Phase II (Page No. 48-55)



Assessment of Ambient Air Quality during Pre-Deepawali, Deepawali and Post-Deepawali Festival, October 2019

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 9 locations (Aliganj, Vikasnagar, Indiranagar, Gomtinagar, Charbagh, Aminabad, Chowk, Alambagh and Amausi) of Lucknow city to assess the impact of fireworks on the environment during the Deepawali festival, 2019. Monitoring results revealed that the respirable particulates during pre-Deepawali, Deepawali and post-Deepawali are well above the National Ambient Air Quality Standards of 60 and 100 µg/m^3 for $PM_{2.5}$ and PM_{10} respectively (Table 1).

During the major event on Deepawali night October 27th, 2019 the mean level of $PM_{2.5}$ increased from 159.2 to 346.5 µg/m^3 over the pre-Deepawali night and reduced to 190.7 µg/m^3 during post-Deepawali night. Similarly on Deepawali night, the level of PM_{10} also increased from 234.1 to 536.5 µg/m^3 over the pre-Deepawali night and reduced to 307.7 µg/m^3 during post-Deepawali 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 Deepawali holidays.

On the Deepawali night $PM_{2.5}$ increased by 117.6% whereas the increase in PM_{10} over the pre-Deepawali night was 129.1%. Further, the higher levels of particulates continued during post-Deepawali night by 19.7% and 31.4% for $PM_{2.5}$ and PM_{10} respectively over pre-Deepawali night levels (Fig. 1).

In case of SO_2, the mean level was found to be within prescribed limits. However, mean level of SO_2 on the Deepawali night increased from 12.9 to 35.7 µg/m^3 and on post-Deepawali mean SO_2 level was 27.0 µg/m^3, which indicates that the levels increased by 176.5% and 109.7% on the Deepawali night and post-Deepawali night respectively over the pre-Deepawali night.

The mean level of NO_2 was found to be within prescribed limits. On Deepawali night the mean NO_2 value increased from 31.6 to 100.7 µg/m^3 over the pre-Deepawali night. On the post-Deepawali night, mean level of NO_2 was increased to 59.3 from 31.6 µg/m^3 on pre Deepawali night. In terms of percentage, NO_2 level increased by 218.1% on Deepawali night and increased by 87.5% on post-Deepawali night over the pre-Deepawali night.

However, the pollution levels were found to be lower this year as compared to 2018. Reduction in particulate matter PM_{10} and $PM_{2.5}$ from last year was found to be about 46% and 49% respectively. This may be due to public awareness campaigns run by our institute CSIR-IITR and other initiatives taken by district administration, Government of Uttar Pradesh and Government of India.

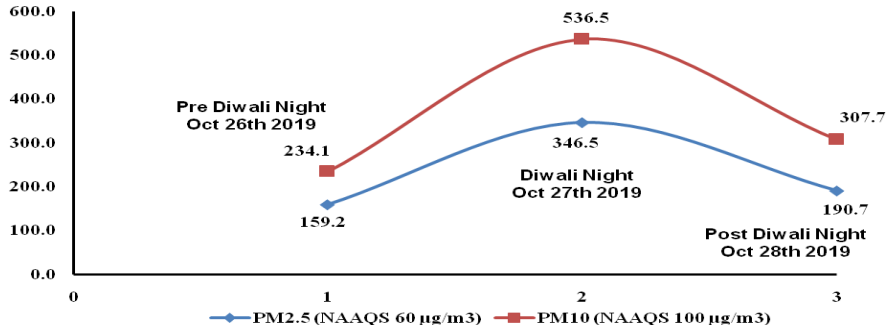


Fig. 1. Profile of respirable particulates (in µg/m^3) during the night time of Deepawali Festival.

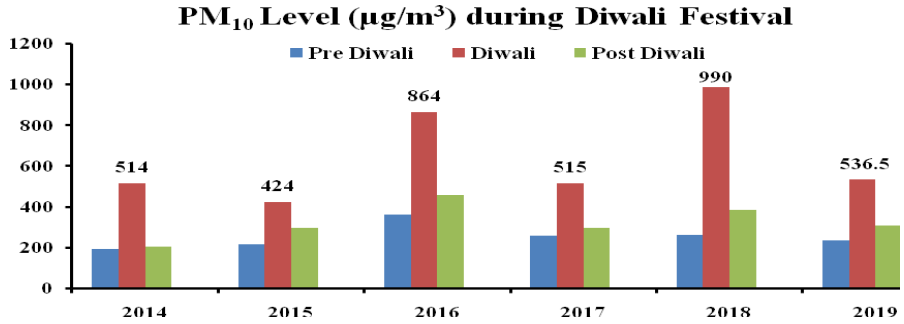


Fig. 2. Levels of respirable particulates (PM_{10}) concentration during 2014, 2015, 2016, 2017, 2018 and 2019 (Night time Deepawali Festival).

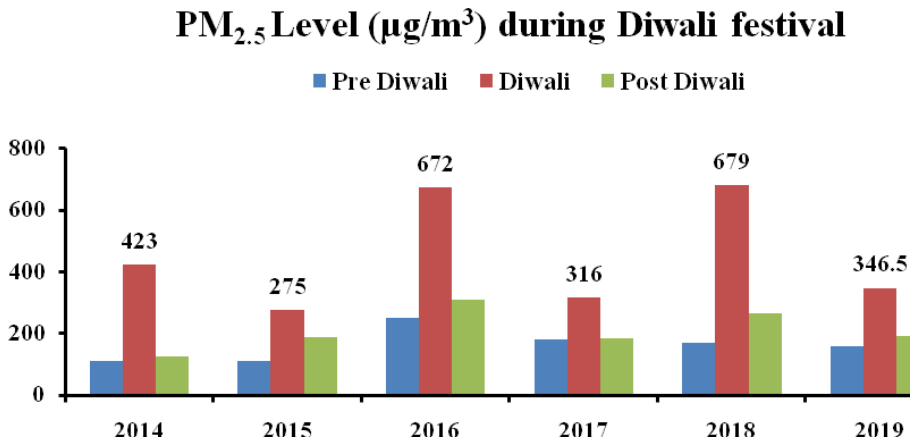


Fig. 3. Levels of respirable fine particulates ($PM_{2.5}$) concentration during 2014, 2015, 2016, 2017, 2018 and 2019 (Night time Deepawali Festival).

Table 1. CSIR-IITR Deepawali 2019 Pollution Survey

Pollutants/ Locations	**Pre-Deepawali 2019** (October 26th 2019)		**On-Deepawali 2019** (October 27th 2019)		**Post-Deepawali 2019** (October 28th 2019)	
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	103.30	198.28	142.15	528.66	267.37	394.66
Vikas Nagar	163.85	175.14	211.47	586.75	305.28	351.58
Indira Nagar	120.42	171.01	213.75	517.18	284.13	302.82
Gomti Nagar	110.36	316.28	245.00	498.61	189.96	307.31
Charbagh	160.75	306.51	383.28	656.11	216.94	281.13
Alambagh	184.76	ND	171.83	489.73	255.20	259.42
Aminabad	216.28	226.46	193.91	549.92	289.83	363.65
Chowk	219.82	310.70	172.39	553.66	162.94	298.61
Amausi	175.62	168.78	248.02	447.48	110.20	210.09
$PM_{2.5}$ ($\mu g/m^3$)						
Aliganj	67.41	73.34	67.25	279.81	113.56	173.19
Vikas Nagar	91.89	101.45	125.02	433.33	210.16	240.53
Indira Nagar	73.46	84.43	104.78	346.82	187.08	233.38
Gomti Nagar	ND	247.36	168.10	298.12	128.17	173.57
Charbagh	115.42	239.86	248.20	486.98	180.39	195.80
Alambagh	132.57	118.53	106.91	310.11	150.33	136.70
Aminabad	167.62	177.78	116.05	386.76	181.81	268.17
Chowk	157.14	266.13	120.41	322.07	104.23	181.97
Amausi	140.83	124.24	97.21	254.24	84.77	112.54
SO_2 ($\mu g/m^3$)						
Aliganj	8.28	11.87	20.97	45.96	17.87	22.24
Vikas Nagar	3.48	5.64	19.24	47.38	16.25	21.18
Indira Nagar	3.55	13.20	23.25	28.96	15.09	32.62
Gomti Nagar	6.77	11.15	15.31	27.47	17.14	28.86
Charbagh	14.81	20.17	29.20	37.99	17.58	21.48
Alambagh	10.19	ND	24.54	27.09	18.46	30.00
Aminabad	5.04	7.82	26.46	24.43	24.40	28.55
Chowk	12.86	19.22	30.29	44.30	25.76	38.99
Amausi	12.49	14.10	18.98	37.36	15.77	19.44
NO_2 ($\mu g/m^3$)						
Aliganj	22.09	31.32	35.17	55.28	34.06	27.25
Vikas Nagar	24.90	29.15	19.25	114.99	29.14	54.09
Indira Nagar	21.64	44.02	83.41	107.32	42.42	42.18
Gomti Nagar	30.40	33.39	40.11	55.19	39.20	55.92
Charbagh	31.54	39.28	92.80	165.28	63.68	67.24
Alambagh	38.86	ND	32.91	70.81	43.97	57.50
Aminabad	43.22	29.80	86.46	144.80	38.06	85.30
Chowk	28.59	33.57	89.59	153.44	61.94	105.96
Amausi	11.76	12.64	30.86	39.03	52.60	38.53

ND= Not Done

Weather condition

Besides sources of pollutants the air quality depends on meteorological factors like temperature, wind speed and wind direction, relative humidity etc. To represent the weather condition we have collected temperature, relative humidity, wind speed and wind direction data from CPCB online monitoring station (http:/cpcb.nic.in) at Talkatora Industrial Centre, Lucknow during the study period (26-28th October, 2019) and presented as wind rose diagram (Fig. 4.). The temperature was found to be in the range of 19.01 to 29.10^{o}C with an average of 23.83^{o}C on 26th October, on 27th it was in the range of 19.59 to 29.12^{o}C, with an average of 24.12^{o}C and on 28th the same values were in the range of 20.45 to 27.71°C with an average of 23.90°C. In case of relative humidity on 26th, 27 and 28th October the mean values were 75% (47.81 to 95%), 67.09 % (46.9 to 86.34) and 68.61 (50.8 to 88.16%) respectively. The wind speed values on 26th, 27th and 28th October were found to be 0.19 m/s (0.07 to 40 m/s) , 0.53 m/s (0.09 to 1.06 m/s) and 0.24 m/s (0.03 to 0.59 m/s) respectively.

During the study period the predominant wind direction was W (West) for 8.21% of the time. The other dominant directions were WSW (West South West) and WNW (West North West) each one for 5.47% of the time. For most of the time (78.08%; calm period) wind speed remained <1.8 km/h and 13.6% of the time it was in between 1.8 to <3.6 km/h (Fig. 4).

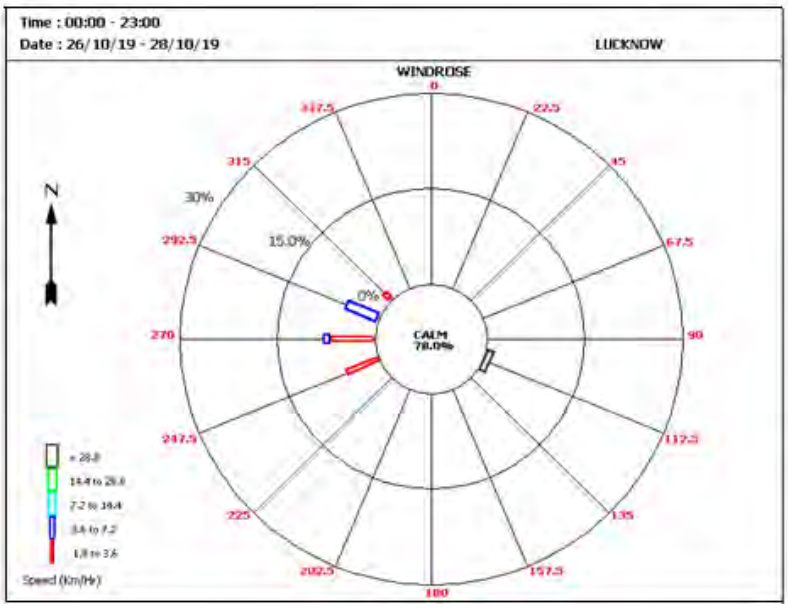


Fig. 4. Windrose diagram during study period (26th to 28th October, 2019) at Talkatora centre, Lucknow (data source htpp:/cpcb.nic.in)

Noise level

Noise level was recorded during Pre-Deepawali, Post-Deepawali and On-Deepawali night to observe the impact of bursting of fire cracker at seven 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 82.1 dB(A) at Indiranagar area whereas minimum was recorded as 71.3 dB(A) at Aminabad on Deepawali 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 in dB(A) on Pre-Deepawali, Deepawali and Post-Deepawali night

Locations	**Pre-Deepawali** (October26th, 2019)	**On-Deepawali** (October 27th, 2019)
Charbagh (10:00-10:30 PM)	68.6	80.2
Chowk (11:00- 11:30 PM)	70.2	78.5
Aliganj (09:00- 30:00 PM	64.2	78.9
Vikas Nagar (07:00- 08:00 PM)	64.6	76.8
Indira Nagar (9:00-9:30 PM)	63.3	82.1
Aminabad (10:00-11:00 PM)	65.6	71.3
Gomti Nagar (08:30 -9:00 PM)	64.8	75.7

CSIR-IITR is constantly working to take forward its mission towards clean environment through programmes like Outreach and Jigyasa and exhibitions during all events organized in the Institute. Under such activities efforts are made to connect the citizens, particularly students to the cause of clean environment. The campaign to minimize the use of fire crackers in the light of adverse health effects of noise and air pollution have been taken up under these awareness programmes. However, it is observed that during festive season like Deepawali, noise and air pollution tends to increase due to firing of crackers. The change in meteorological conditions in the beginning of winter season i.e. low wind speed and low temperature restricts dispersion, dilution and transport of air pollutants. During winter this kind of situation usually prevails in most of the cities in northern India where Air Quality Index (AQI) was reported in the category of poor, very poor or severe by CPCB.

The results of survey during Deepawali festival clearly indicate significant deterioration of air quality in Lucknow city on festival day from the pre-Deepawali day. On post Deepawali day it again dropped and reached close to pre-Deepawali day. Children, senior citizen and people suffering from respirable diseases are at risk due to air pollutants generated from firing of crackers. Particularly, smoke and fumes from firing of crackers include elements such as aluminum, antimony, sulphide, perchlorate, barium nitrite, lithium, copper, strontium, cadmium etc., which may cause Alzheimers disease, thyroid imbalances, gastrointestinal problems, muscular weakness, respiratory problems, hormonal disbalance etc. It may also cause cancer. Besides human, affects are also seen on other animals due to high levels of air and noise pollution. Firework events also affect surface soil quality and ultimately create water pollution and generate huge quantity of additional solid waste. Therefore the storage, sale and use of crackers creating noise more than prescribed levels and emitting toxic smoke and fumes should be checked as per the guidelines. As far as possible the use of fire crackers should be discouraged and minimized to maintain clean air quality in the festival season.

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Recognitions
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- Indian Factories Act (Drinking water)
- Bureau of Indian Standards (Synthetic Detergents)
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Technologies Developed/ Available
- Oneer- A Novel Solution for Safe Drinking Water
- Portable Water Analysis Kit
- Mobile Laboratory for Environment and Human Health
- AO Kit for Rapid Screening of Argemone in Mustard Oil
- MO Check for Detection of Adulterant Butter Yellow in Edible Oils

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