Assessment of Ambient Air Quality of Lucknow City

Pre-Monsoon 2019

Findings of a Random Survey

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Salient Features of the Study

❖ **Geographical Position**	:	26^{o} 52' N Latitude 80^{o} 56' E Longitude 128 m above Sea Level
❖ **Area**	:	310 sq. km.
❖ **Population**	:	28,15,033 as per 2011 Census
❖ **Projected Population**	:	65 lakhs as per Master Plan 2031
❖ **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 Metals and Noise Levels
❖ **Study Conducted by**	:	Environmental Monitoring Division CSIR-IITR, Lucknow

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

1.0 SUMMARY

The study was carried out during the months of April-May, 2019 to assess the status of air quality by monitoring and assessment of some selected air pollutants namely Respirable Suspended Particulate Matter (RSPM or PM_{10}), Fine Particulate Matter ($PM_{2.5}$), Sulphur Dioxide (SO_2), Nitrogen Dioxide (NO_2), trace metals-Lead (Pb) and Nickel (Ni) 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 102.3 to 290.5 µg/m^3 with an average of 178.5µg/m^3. The 24 hours concentration of $PM_{2.5}$ was found to be in the range of 51.5 to 130.7 µg/m^3 with an average of 84.3 µg/m^3. The average values of PM_{10} and $PM_{2.5}$ irrespective of locations were found to be above the permissible limit (100 µg/m^3 for PM_{10} and 60 µg/m^3 for $PM_{2.5}$ prescribed by CPCB, 2009). Twenty four hours concentration of SO_2 and NO_2 were found to be in the range of 4.2 to 14.3 and 17.2 to 89.1 µg/m^3 with average concentrations of 7.6 and 37.4 µg/m^3 respectively and all the mean values were below the permissible limit (80 µg/m^3 for both SO_2 and NO_2 prescribed by CPCB, 2009). The mean level of trace metals were Pb = 35.07 and Ni = 4.49 ng/m^3. *Noise levels during day and night time were found to be in the range of 65.3 to 86.6 dB (A) and 56.0 to 67.9 dB (A) respectively which was above the respective permissible limits.*

1.1 INTRODUCTION

Air pollution has been aggravated in most of the Indian cities over the years by higher levels of energy consumption, increasing traffic and motorization, industrialization, construction and road dust entrainment and other enhanced domestic activities due to increased city population. The emissions of these ground and elevated level sources significantly deteriorate the air quality of city and subsequently have the greatest impact on the health of the population exposed to it. The key pollutants such as PM_{10}, $PM_{2.5}$, SO_2, NO_2, O_3, CO, HC and PAH's are major culprits for the environmental, health and climate damage. Most localized sources have significant forte to introduce these criteria pollutants in the ambient environment. Although the pollutants are regulated with compliance limits, the synergetic impact of these pollutants gives chronic and instant consequences.

The air pollution concentration vary spatially and temporarily causing the air pollution pattern to change with different locations and time due to changes in strength of sources, meteorological and topographical condition. It is necessary to assess the present and anticipated air pollution through continuous air quality survey/monitoring programs. Therefore, many regulatory bodies and health organizations over different countries in the world have started early for ambient air pollution monitoring, and the monitoring data is being used for establishment of a relation between health impact due to source emissions and subsequent management plans to control the source strength. The long-term air quality monitoring data are typically used to tease out patterns like spatial and temporal differences in pollution that support air pollution control policy. Further, the documentation of monitoring data are a sophisticated endeavor, either to record the rate of progress towards attaining the ambient air quality standard or to show that the standard has been achieved.

In the view of above scope, CSIR-Indian Institute of Toxicology Research (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. Lucknow city is with hot dry winds and humid climate during the pre-monsoon

season (April, May and June). Construction, industrial, commercial and road transportation activity based air borne particles mainly effect the city ambient environment. The summer season of city has the greater influence of dust storm hit, dry soil dust entrainment due to natural winds blows and local on road vehicles movement.

Currently, some portion of Lucknow city was begun with convenient metro system which has significant impact on city air pollution positively by avoided road transportation. Besides, recently constructed flyovers and express highways in and around the city also give a positive impact on air pollution levels of 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 living near roadways. The number of different categories of vehicles registered with RTO (Regional Transport Office) 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 the Lucknow city. Uttar Pradesh State Road Transport Corporation (UPSRTC) introduced bus services under the banner "*Lucknow City Transport Services Limited*" on different routes of Lucknow city. The details of bus routes and number of buses plying as on 31.03.2019 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 is 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 9 locations during pre monsoon (April-May), 2019 with respect to PM_{10}, $PM_{2.5}$ SO_2, NO_2, trace metals and noise level with the following aims and objectives.

- *To assess the ambient air quality with respect to PM_{10}, $PM_{2.5}$, SO_2, NO_2, and trace metals (Pb and Ni) 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)	9
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)	Commercial (Sensitive)
9	Amausi	Industrial

Table 7
Parameters and Methodology for Air Quality Monitoring

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

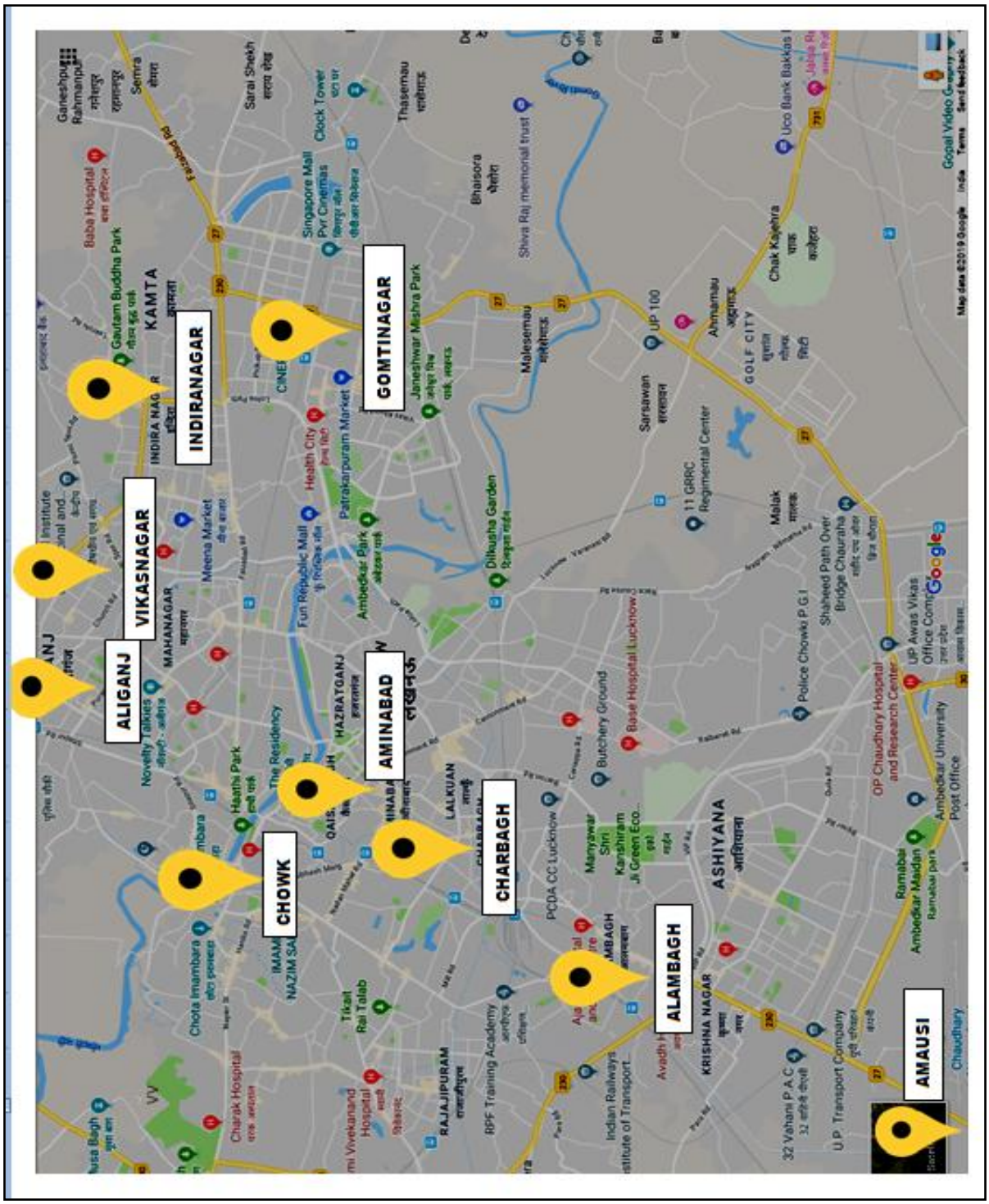


Figure 1: Ambient Air Pollution Monitoring Locations in Lucknow City

1.3 RESULTS

The detailed results of air quality monitoring are presented in Table 8 and Figure 2 and 3.

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 170.7 to 185.7 µg/m^3 with an average of 180.1 µg/m^3. In commercial areas (Charbagh, Alambagh, Aminabad and Chowk) the average concentrations of PM_{10} were in the range of 151.1 to 190.9 µg/m^3 with an average of 174.3 µg/m^3 respectively. In industrial area (Amausi), the average concentration of PM_{10} was 189.2 µg/m^3.

The maximum 24 hours mean concentration of PM_{10} was observed in Vikas Nagar (185.7 µg/m^3) in residential area and Charbagh (190.9 µg/m^3) in commercial areas. All the values of PM_{10} were above the prescribed National Ambient Air Quality Standard (NAAQS) of 100 µg/m^3 for industrial, residential, rural and other areas respectively.

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

In residential areas (Aliganj, Vikas Nagar, Indira Nagar and Gomti Nagar), the 24 hours average concentrations of $PM_{2.5}$ were in the range of 83.0 to 88.2 µg/m^3 with an average of 85.2 µg/m^3. In commercial areas (Charbagh, Alambagh, Aminabad and Chowk) the average concentrations of $PM_{2,5}$ were in the range of 75.3 to 92.0 µg/m^3 with an average of 84.7 µg/m^3 respectively. In industrial area (Amausi), the average concentration of $PM_{2.5}$ was 79.8 µg/m^3.

The maximum 24 hours mean concentration of $PM_{2.5}$ was observed in Vikas Nagar (88.2 µg/m^3) residential area and Charbagh (92.0 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.

1.3.3 Sulphur Dioxide (SO_2)

In residential areas (Aliganj, Vikas Nagar, Indira Nagar and Gomti Nagar) the mean levels of SO_2 were in the range of 6.5 to7.5 µg/m^3 with an average of 7.0 µg/m^3. In commercial areas (Charbagh, Alambagh, Aminabad and Chowk) the average concentrations of SO_2 were in the range of 6.1 to 10.3 µg/m^3 with an average of 8.1 µg/m^3. In industrial area (Amausi), the mean level of SO_2 was 7.8 µg/m^3.

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

1.3.4 Nitrogen Dioxide (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 29.3 to 37.9 µg/m^3 with an average of 34.0 µg/m^3. In commercial areas (Charbagh, Alambagh, Aminabad and Chowk) the average concentrations of NO_2 were found in the range of 36.0 to 54.5 µg/m^3 with an average of 42.8 µg/m^3. In industrial areas (Amausi), the average concentration was 29.8 µg/m^3.

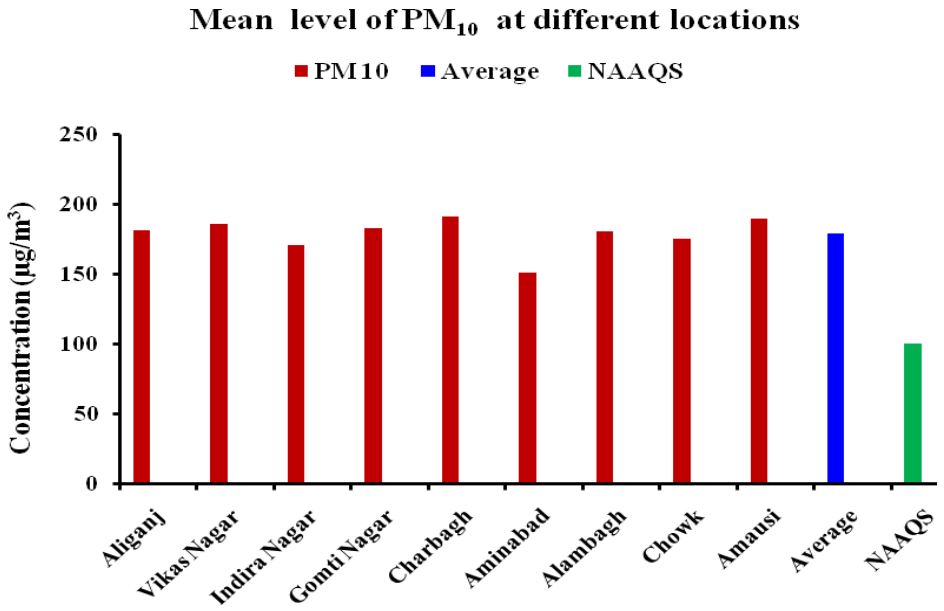
All the values of NO_2 were within the prescribed NAAQS of 80 µg/m^3 for all the monitoring locations.

Table 8

Concentration (µg/m^3) of PM_{10}, $PM_{2.5}$, SO_2 and NO_2 during Pre Monsoon 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	107.8	253.8	181.4	60.7	118.1	85.1	4.7	11.7	6.5	23.1	51.0	36.2
Vikas Nagar	126.4	256.8	185.7	68.6	120.5	88.2	4.6	9.5	7.2	26.6	39.9	32.5
Indira Nagar	135.5	226.5	170.7	51.5	110.9	83.0	5.2	10.6	7.5	17.2	38.3	29.3
Gomti Nagar	119.3	245.9	182.4	58.6	125.3	84.3	4.3	9.5	6.8	17.8	54.5	37.9
Commercial												
Charbagh	118.9	243.1	190.9	53.7	112.1	92.0	7.8	13.0	10.3	29.4	76.2	41.0
Alambagh	119.6	240.9	180.1	65.1	130.7	86.7	4.2	12.5	7.8	34.4	89.1	54.5
Aminabad	102.3	214.4	151.1	63.6	104.0	75.3	4.7	7.7	6.1	20.4	69.4	36.0
Chowk	136.8	234.6	175.1	56.1	127.4	84.6	6.0	13.3	8.0	18.7	76.3	39.5
Industrial												
Amausi	122.0	290.5	189.2	54.4	104.3	79.8	5.9	14.3	7.8	21.9	48.3	29.8
NAAQS	100			60			80			80		
WHO Guidelines	50			25			20			40*		

N=8, *= Annual Average, NAAQS=National Ambient Air Quality Standard



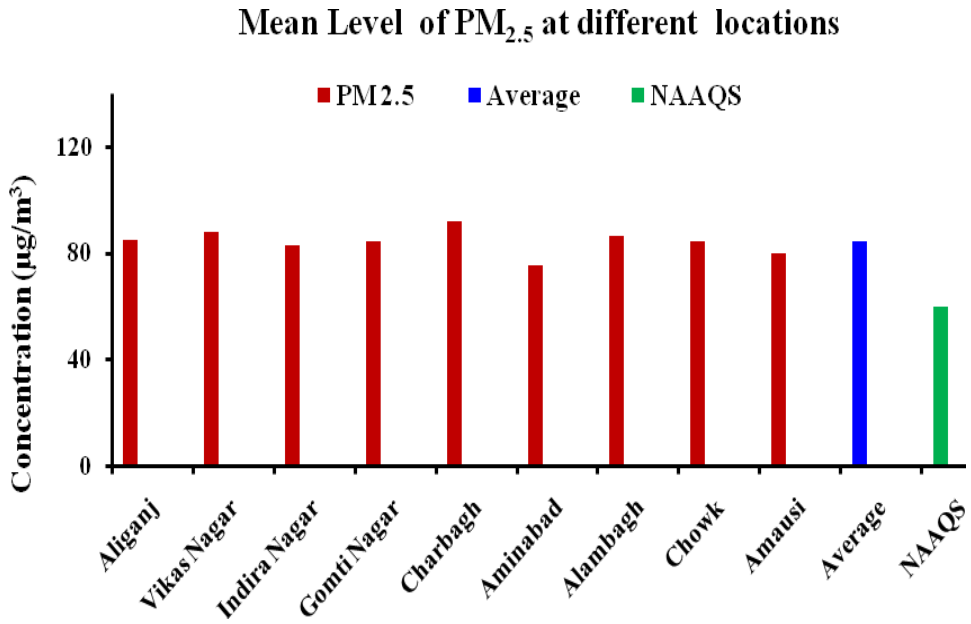


Figure 2: Concentration (µg/m^3) of PM_{10} and $PM_{2.5}$ in different areas of Lucknow city during Pre Monsoon Season (2019) compared with prescribed National Ambient Air Quality Standard (NAAQS)

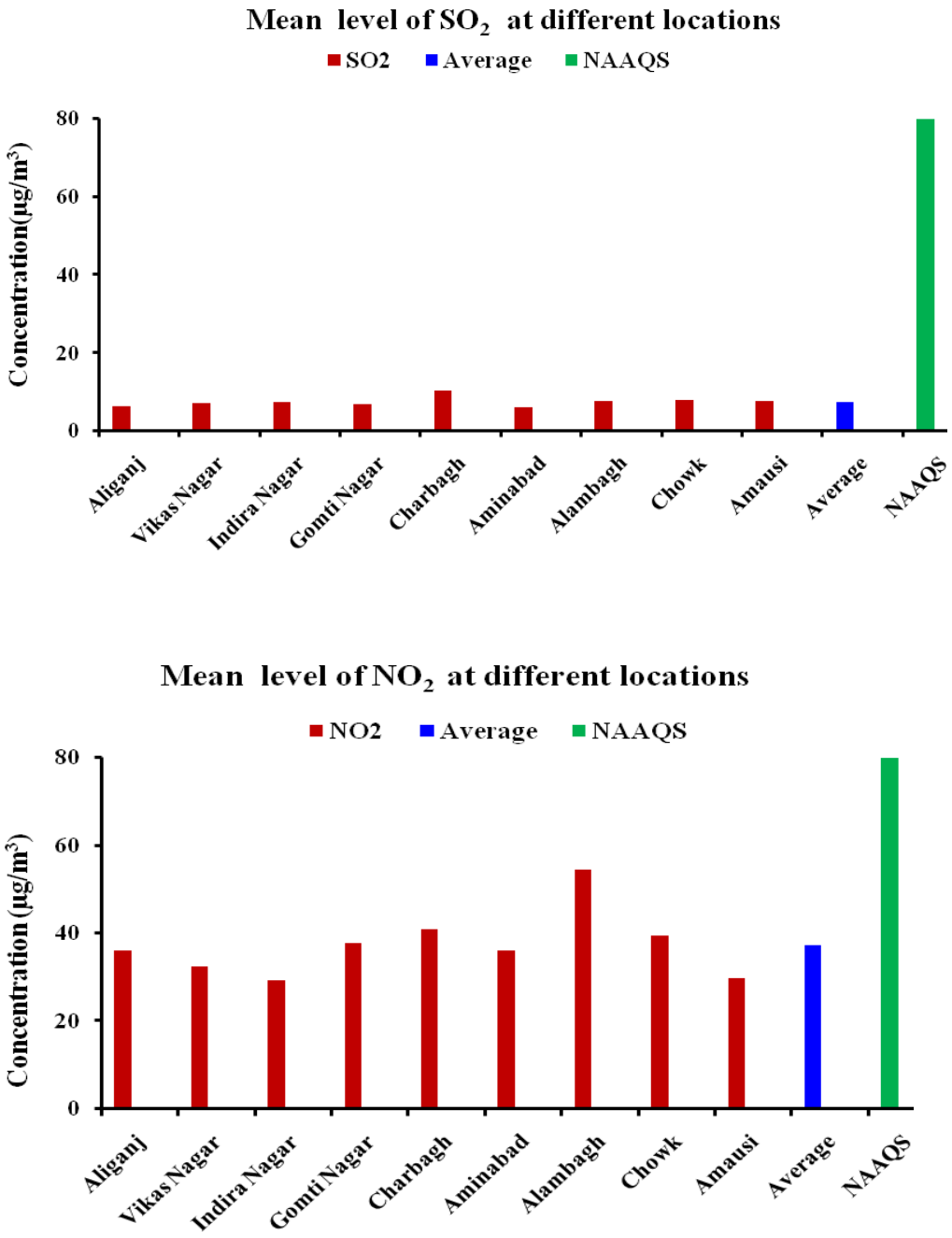


Figure 3: Concentration (µg/m^3) of SO_2 and NO_2 in different areas of Lucknow city during pre monsoon season (2019) compared with prescribed National Ambient Air Quality Standard (NAAQS)

1.3.5 Trace Metals in Ambient Air (RSPM)

The trace metals (Pb and Ni) were estimated in ambient air associated with PM_{10} at 9 monitoring locations. The results are presented in Table 9. The 24 hr mean concentration of metals were found to be Pb = 35.07 (14.49 – 87.53) and Ni = 4.49 (1.60 – 16.95) ng/m^3.

Table 9

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

S.No.	Location	Pb	Ni
1	Aliganj	24.74	2.68
2	Vikas Nagar	31.77	2.47
3	Indira Nagar	14.49	3.29
4	Gomti Nagar	27.91	3.79
Average		**24.73**	**3.06**
5	Charbagh	31.31	16.95
6	Alambagh	29.0	1.6
7	Aminabad	32.24	6.0
8	Chowk	36.65	1.23
Average		**32.3**	**6.44**
9	Amausi	87.53	2.41
NAAQS		**1000**	**20***

N= 1, *=Annual Average

1.3.6 Noise Level

The noise monitoring data recorded during the pre monsoon period (May, 2019) is presented in Table 10.

In residential areas, the day and night time noise levels were recorded between 65.3 to 72.7 and 56.0 to 62.9 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 67.2 to 86.6 and 60.1 to 67.9 dB(A) respectively. Noise level at all the

commercial sites during day and night time were found above the prescribed limits of 65 and 55 dB(A) respectively. In industrial area Amausi, the day and night time noise levels were recorded 76.2 and 66.4 dB(A) respectively. Noise levels at industrial area was found to be exceeded during day time and night time were recorded lower than the prescribed limits of 75.0 and 70.0 dB(A) respectively.

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

S. No.	Area	Location	Noise level dB(A)	
			Day	Night
1	**Residential**	Aliganj	72.4	61.5
		Vikas Nagar	65.3	56.0
		Indira Nagar	66.0	62.9
		Gomti Nagar	72.7	58.3
		Standard	**55**	**45**
2	**Commercial**	Charbagh	86.6	67.9
		Alambagh	67.2	62.4
		Aminabad	75.1	60.1
		Chowk	70.3	66.3
		Standard	**65**	**55**
3	**Industrial**	Amausi	76.2	66.4
		Standard	**75**	**70**

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 were found to be comparatively 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 year. 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 concentrations of SO_2 were found at all locations 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. The residential areas showed a mixed trend with two locations showing a decreasing trend, and an increasing trend being observed in the other two. All the commercial 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).

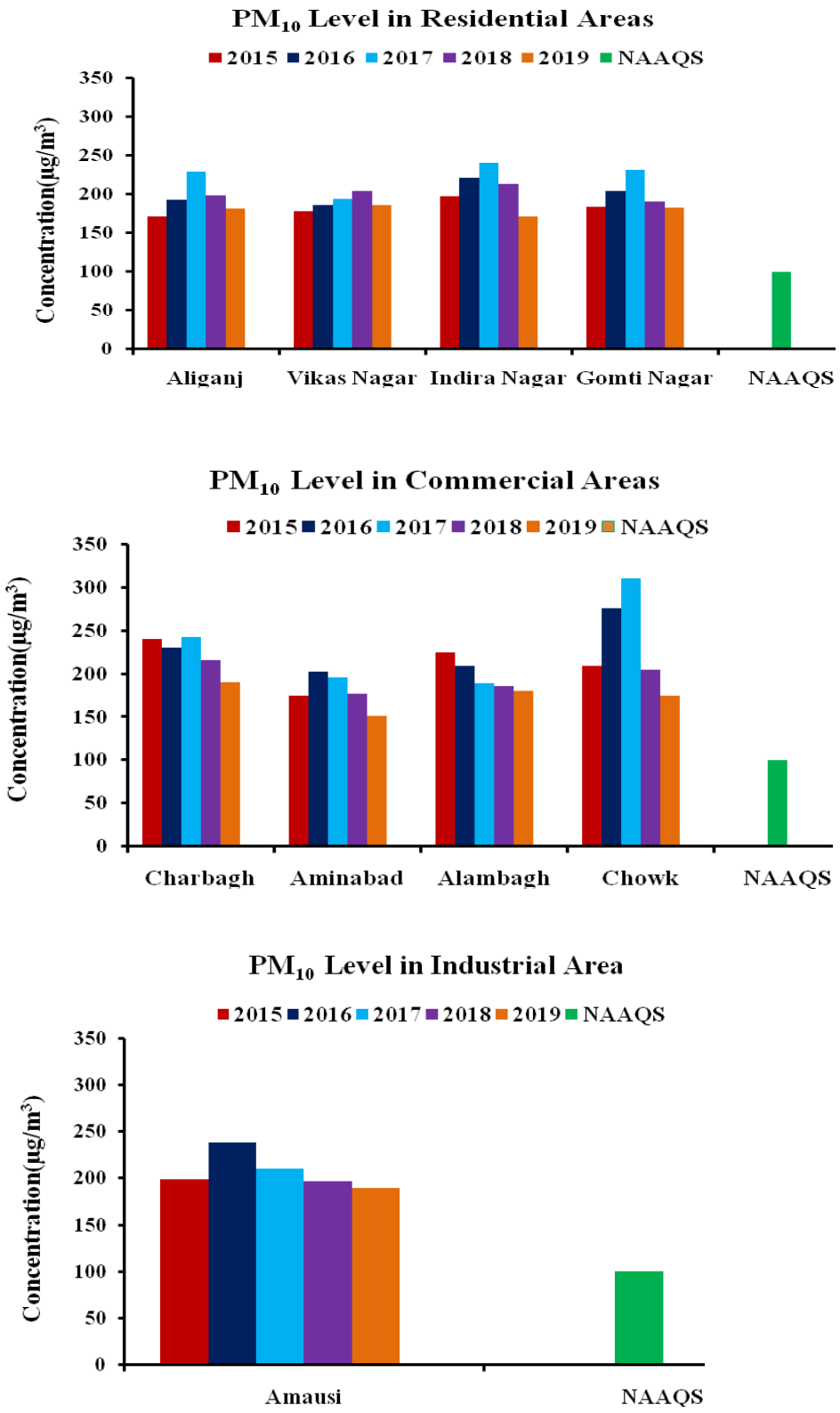


Figure 4: Concentration (µg/m^3) of PM_{10} **(**RSPM**)** in Residential, Commercial and Industrial areas of Lucknow city during 2015 to 2019 and compared with prescribed National Ambient Air Quality Standard (NAAQS)

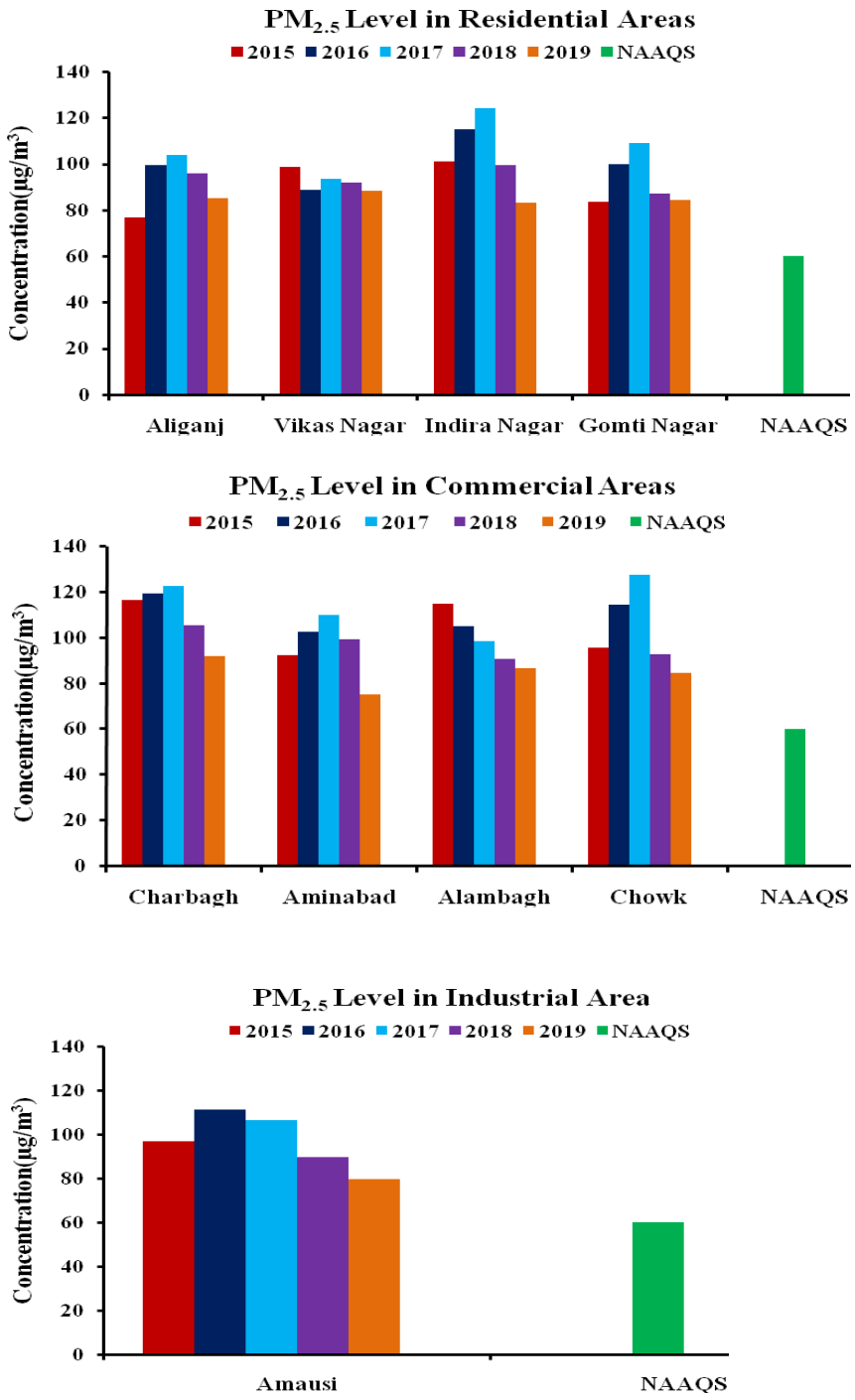


Figure 5: Concentration (µg/m^3) of $PM_{2.5}$ in Residential, Commercial and Industrial areas of Lucknow city during 2015 to 2019 and compared with prescribed National Ambient Air Quality Standard (NAAQS)

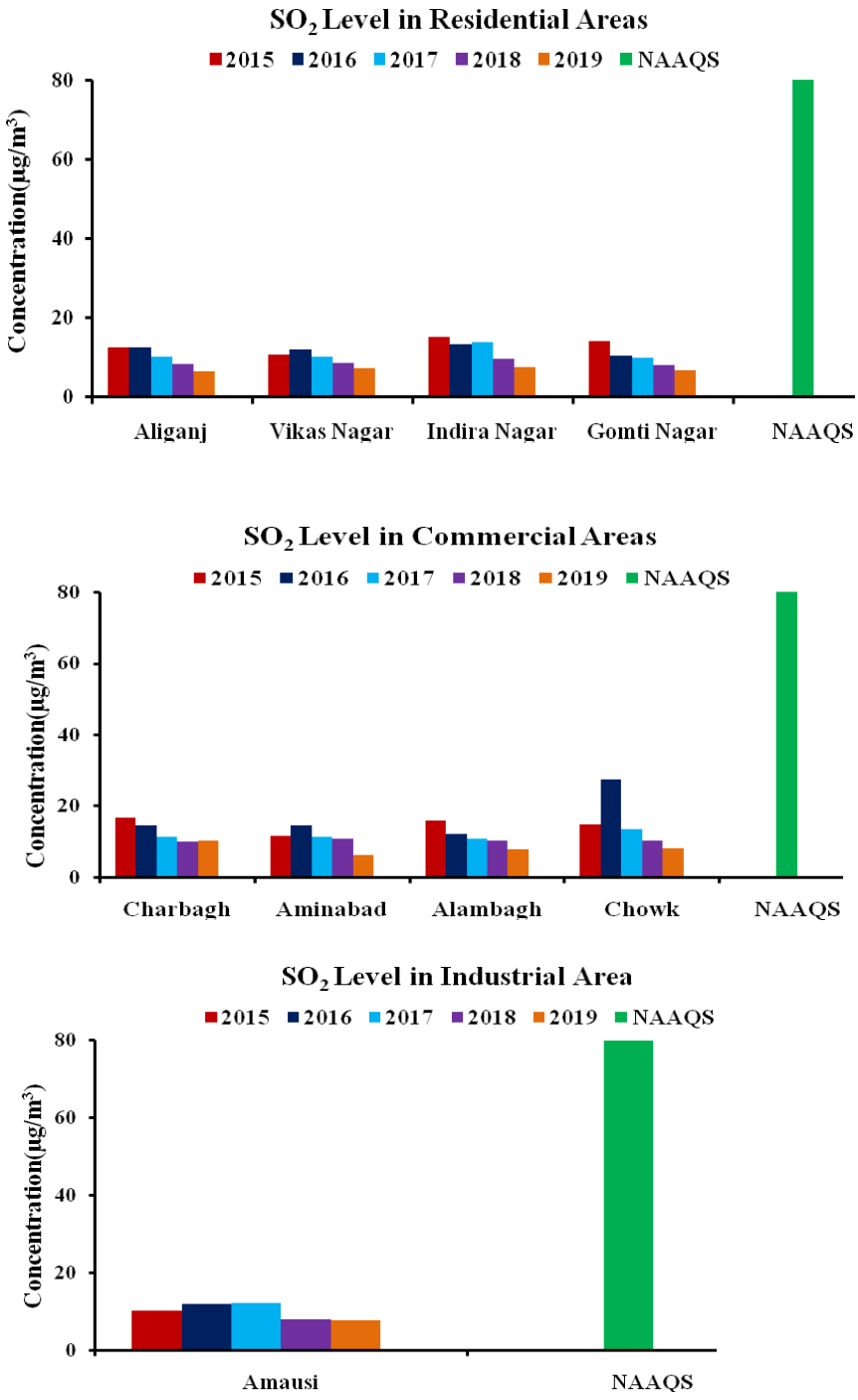


Figure 6: Concentration (µg/m^3) of SO_2 in Residential, Commercial and Industrial areas of Lucknow city during 2015 to 2019 and compared with prescribed National Ambient Air Quality Standard (NAAQS)

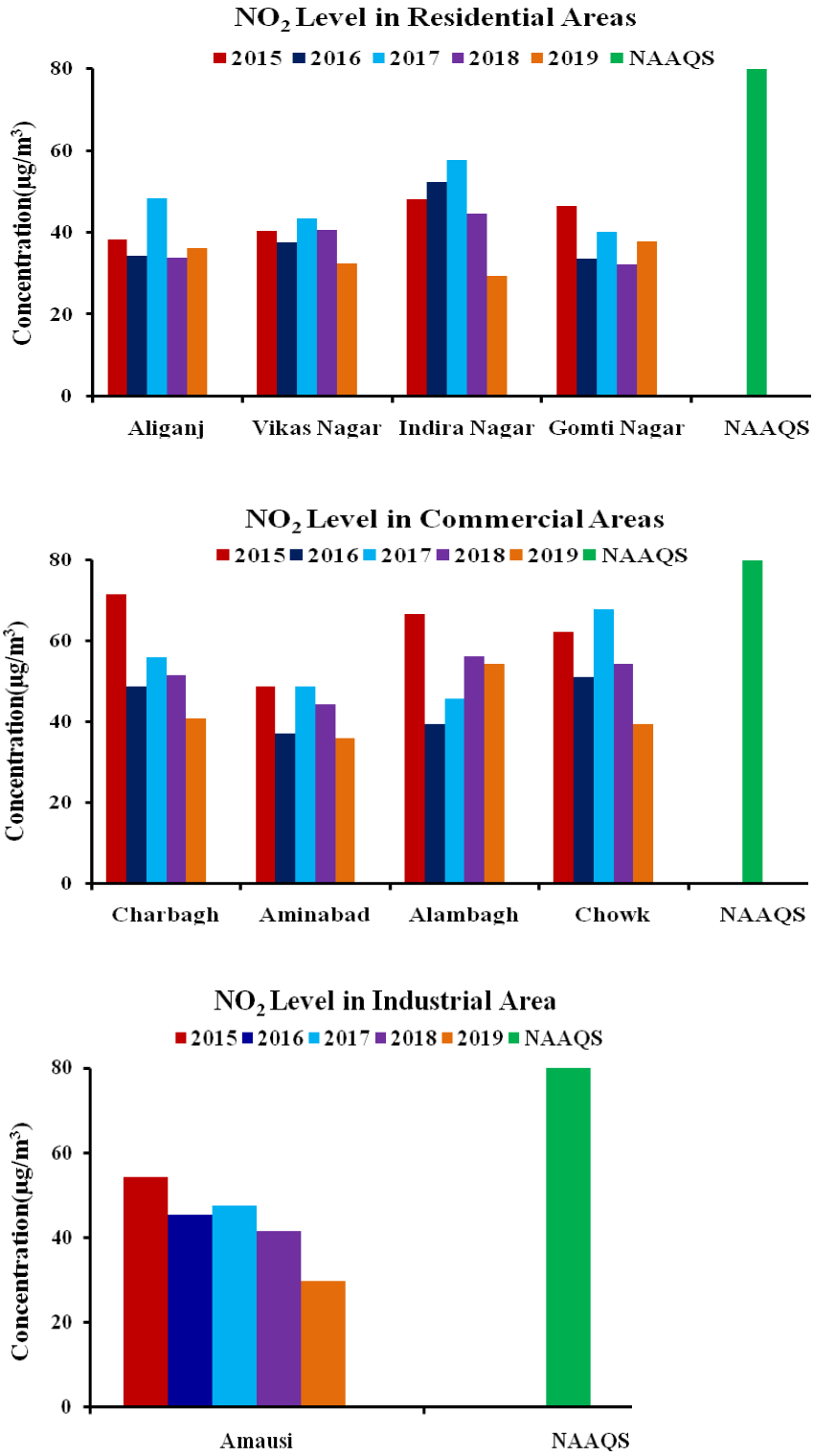


Figure 7: Concentration (µg/m^3) of NO_2 in Residential, Commercial and Industrial areas of Lucknow city during 2015 to 2019 and compared with prescribed National Ambient Air Quality Standard (NAAQS)

1.4.5 Lead (Pb)

The level of Pb during pre monsoon since 2015 is presented in Figure 8 for all the locations. The residential areas showing a decreasing trend at all the residential areas, commercial areas and also in industrial area.

1.4.6 Nickel (Ni)

The level of Ni during pre monsoon since 2015 is presented in Figure 9 for all the locations. The residential areas showing a decreasing trend at all the residential areas, commercial areas and also in industrial area.

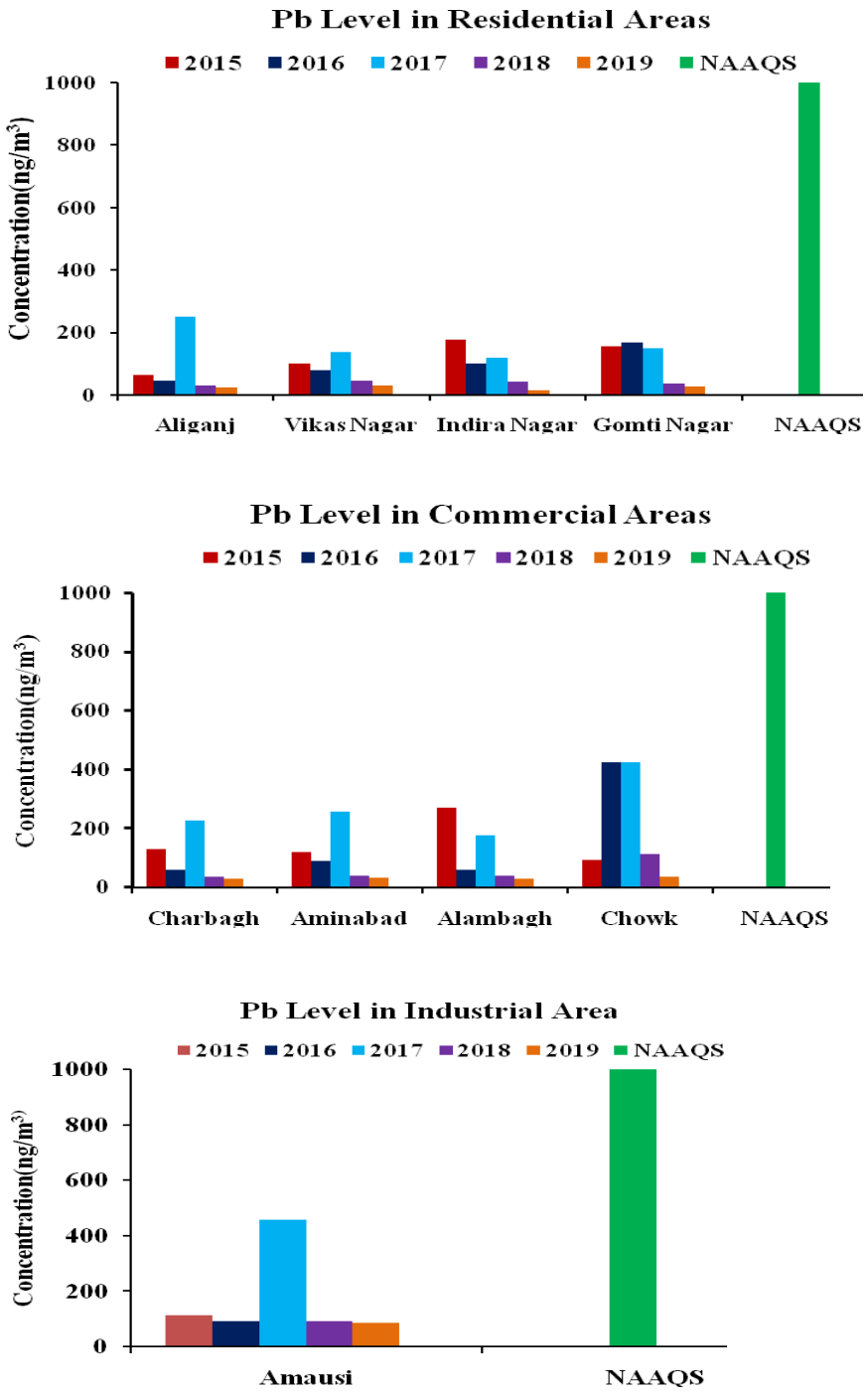


Figure 8: Concentration (ng/m^3) of Lead (Pb) in Residential, Commercial and Industrial areas of Lucknow city during 2015 to 2019 and compared with prescribed National Ambient Air Quality Standard (NAAQS)

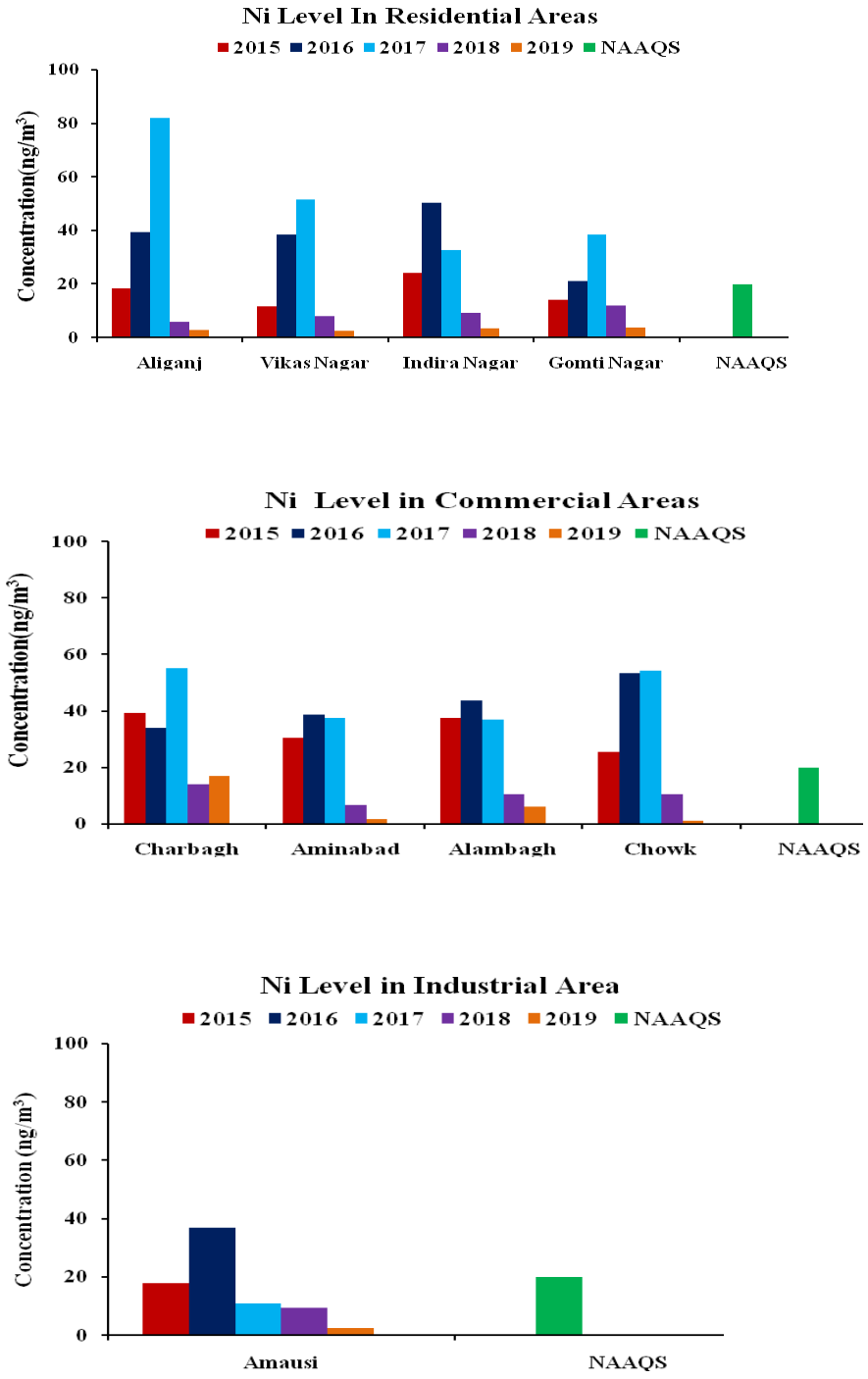


Figure 9: Concentration (ng/m^3) of Nickel (Ni) in Residential, Commercial and Industrial areas of Lucknow city during 2015 to 2019 and compared with prescribed Annual National Ambient Air Quality Standard (NAAQS)

1.4.7 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:

1.4.7.1 Day time Noise Level

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

1.4.7.2 Night time Noise Level

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

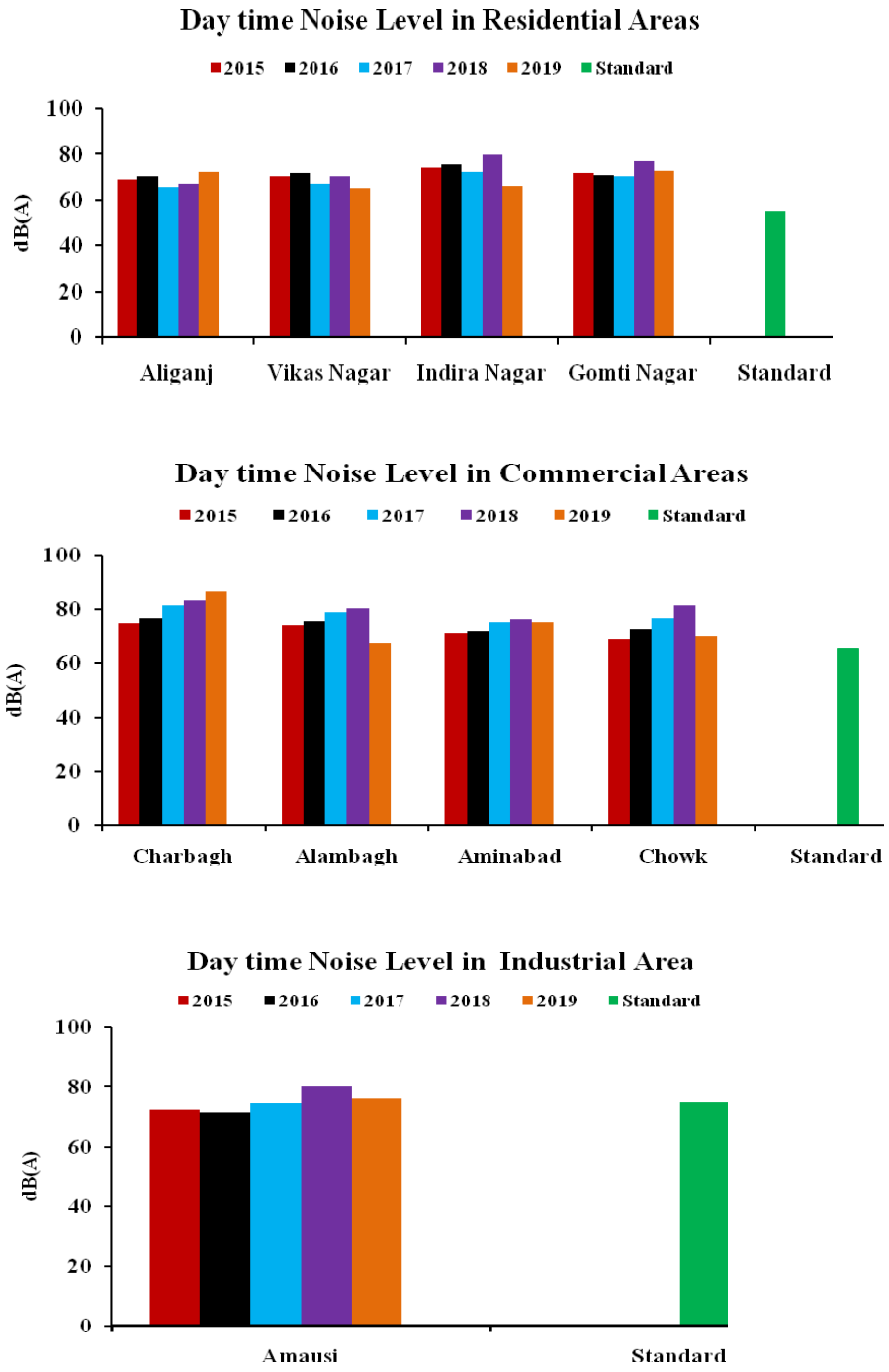
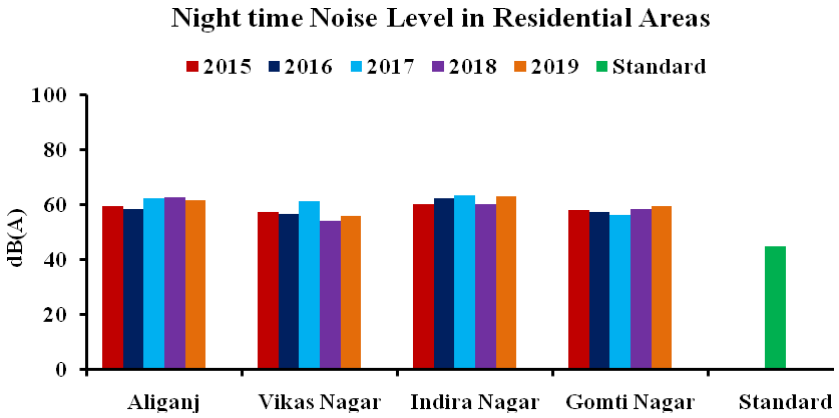
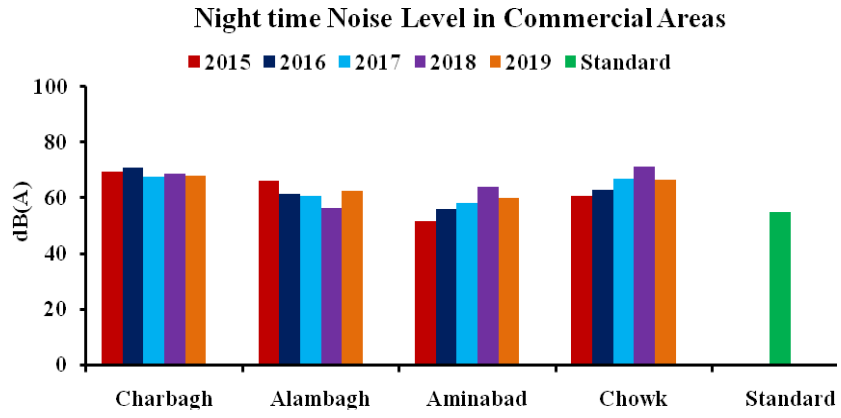


Figure 10: Comparison of day time Noise Level dB(A) in different areas of Lucknow city (2015-2019)





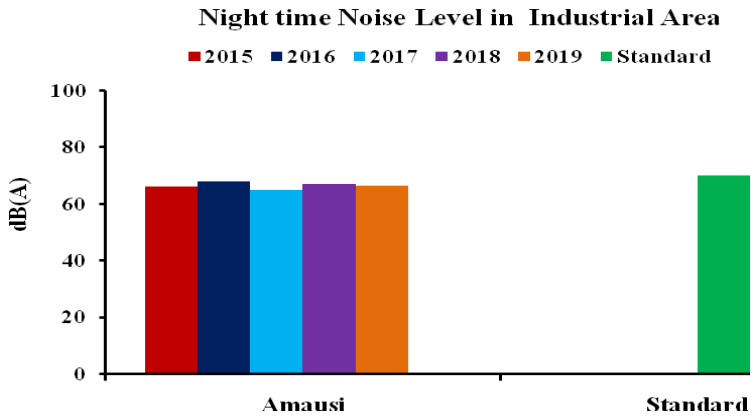


Figure 11: Comparison of night time Noise Level dB(A) in different areas of Lucknow city (2015-2019)

1.5 HEALTH EFFECTS

The air pollution levels for different pollutants are observed to be higher than the NAAQS-2009 in most of the Indian cities. The newly introduced indicator i.e. Air Quality Index was also recorded to be in the range of Poor (201-300), Very Poor (301-400) and Severe (>400) in various cities. Higher levels of air pollutants including metals have adverse effects on human and environmental health. Air Pollution creates series of significant health problems such as premature death, aggravated asthma, acute respiratory symptoms, and decreased lung function in the form of shortness of breath and chronic bronchitis etc. Particulate matter is also a major cause of visibility impairment enhancing coefficient of haze in many parts of Asian countries and United States because these particles can scatter and absorb light. Further fine particles can remain suspended in air and travel long distances across regional and international borders without sinking and settling. Numerous epidemiological studies indicate that an increase in particulate matter concentration is associated with increased mortality; increased hospitalization for respiratory and cardiovascular diseases increased respiratory symptoms and decreased lung functions.

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

Elevated levels of noise have adverse effects varying from hearing loss to annoyance. Annoyance and psychological damage would occur at much lower noise levels.

It is known fact PM_{10} and $PM_{2.5}$ levels increase the mortality and morbidity in the exposed people. The exact mechanism for the toxicity of air born particles is yet to be known. The degree of effeteness depends on the physicochemical properties of the PMs which depend on the level of associated trace metals, organic chemicals as well as the other pollutants. Overall, the effects/toxicity depends on the synergistic effects of physicochemical properties of PMs and environmental circumstances including receptors conditions. Among the trace elements, only Pb and Ni have been monitored and measurements are found to be within the prescribed limits.

The inorganic components constitute a small portion by mass of the particulates; the high level of Pb can induce severe neurological and hematological effects on the exposed population especially children. Details of pollutants effect is given below.

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

- Fine air born particulate matter for the diameter ≤ 2.5 µm, when inhaled would penetrate beyond the larynx.
- 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 Health Effects of 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, particularly likely to occur in people suffering from

asthma and chronic lung disease, whose airways are often inflamed and easily irritated.

- Oral inhalation of larger volumes may reach the segmental bronchi and damage the organ and exposure of the eyes (eg. in an industrial accident) can cause severe burns and resulting in the loss of vision.
- Repeated or prolonged exposure to moderate concentrations may cause inflammation of the respiratory tract, wheezing and lung damage other health effects include headache, general discomfort and anxiety.

1.5.3 Health Effects of Oxides of Nitrogen (NO_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 lowering the resistance to diseases such as pneumonia and influenza.
- Extremely high-dose exposure (as in a building fire) to NO_2 may result in pulmonary edema, diffuse lung injury and development of acute or chronic bronchitis.
- Industrial exposures to nitric oxide can cause unconsciousness, vomiting, mental confusion, and damage to the teeth.
- Exposure to low levels of nitrogen oxides in smog can irritate the eyes, nose, throat and lungs and can cause coughing, shortness of breath, fatigue, and nausea.

1.5.4 Health Effects of Trace elements Lead (Pb)

- Lead is neuro-toxic. Impairment of neurodevelopment in children, effects 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 are an allergic reaction, 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.

1.5.5 Health Effects of Noise Pollution

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

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 pre monsoon (April-May), 2019 we have monitored air pollutants such as PM_{10}, $PM_{2.5}$, SO_2, NO_2 and trace metals (Pb and Ni) for the assessment of ambient air quality. Besides, we have also monitored noise level during day and night time at 9 locations. The results revealed as follows-

- The RSPM (PM_{10}) level at all the monitoring locations of residential, commercial and industrial areas were higher than the NAAQS.
- The mean level of Fine particles ($PM_{2.5}$) at all the monitoring locations of residential, commercial and industrial areas was higher than the NAAQS.
- The concentration of gaseous pollutants, SO_2 and NO_2 were below the prescribed NAAQS (80 µg/m^3) at all the locations but showed slightly lower values compared to previous year.
- The noise level at all the locations during day and night time showed higher level than their respective permissible limits.
- Overall results indicate that all the parameters monitored showed slightly decreasing trend 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. Pressure horns to be removed from all vehicles and avoid/ minimize use of horn.
19. Connectivity to metro stations from surrounding areas by electric vehicles.
20. Heavy dust removal system to be installed at major traffic point which may be operated during peak hours.

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Recognitions

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

Technologies Developed/ Available

- 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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