Assessment of Ambient Air Quality of Lucknow City

Pre-Monsoon 2020

Findings of a Random Survey

सीएसआईआर-भारतीय विषविज्ञान अनुसंधान संस्थान
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Salient Features of the Study

- **Geographical Position** : 26° 52' N Latitude
  80° 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 31/03/2020** : 24,07,190
- **Growth of Vehicle over 2018-2019** : 9.70 %
- **Total No. of Filling Stations (Petrol/Diesel/CNG)** : 106
- **Consumption of Petrol** : 2,32,383 kL
- **Consumption of Diesel** : 2,13,315 kL
- **Consumption of CNG** : 4,23,59,025 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, 2020

(National Lockdown Episodic Impact on Air Quality in Lucknow)

1.0 SUMMARY

The study was carried out during the months of March-May, 2020 encompassing four lockdown (LD) periods; LD-1.0 (25th March- 14th April), LD-2.0 (15th April- 3rd May), LD-3.0 (4th-17th May) and LD-4.0 (18th-31st May), 2020 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 8 representative locations, categorized as residential (four), commercial (three) and industrial (one) areas in Lucknow city. The results revealed the 24 hours concentration of PM_{10} during lockdown periods to be in the range of LD-1.0= 43.2 to 98.7, LD-2.0= 50.6 to 115.5, LD-3.0= 62.9 to 129.8 and LD-4.0= 52.6 to 162.8 µg/m^3 with an average of 75.0, 88.3, 87.4 and 111.9 µg/m^3 respectively. Overall the PM_{10} concentration decreased by 44.9% over the previous year. Also the 24 hours concentration of $PM_{2.5}$ during lockdown periods were in the range of LD-1.0= 21.7 to 69.7, LD-2.0=37.1 to 75.5, LD-3.0= 29.1 to 74.5 and LD-4.0= 42.3 to 95.9 µg/m^3 with an average of 44.8, 51.8, 53.7 and 63.2 µg/m^3 respectively. The $PM_{2.5}$ concentration was found to decrease by 35.2% over the previous year. During first three lockdowns (LD-1.0, LD-2.0 and LD-3.0), the average level of PM_{10} and $PM_{2.5}$ in city was found to be under the permissible limit (100µg/m^3 for PM_{10} and 60µg/m^3 for $PM_{2.5}$ prescribed by CPCB,2009) and only in LD-4.0 it crossed the limits. The concentration of gaseous pollutants SO_2 and NO_2 were found to be below the national permissible limits (80µg/m^3). Overall the mean concentrations were found to be decreased by 18.6% for SO_2 and 27.7% for NO_2 over the previous year. The mean level of trace metals were Pb = 10.44 and Ni = 3.48 ng/m^3. Noise levels during day and night time were found to be in the range of 54.4 to 70.2 dB (A) and 42.7 to 47.8 dB (A) respectively which was above the respective permissible limits during day time and within it during night time.

1.1 INTRODUCTION

Our country has observed an increasing number of acute air pollution episodes in the past few years in many cities which is a growing concern in our country. Air quality data of cities is becoming increasingly available and the science underlying the related health impacts is also evolving rapidly. Since air pollution continues to rise at an alarming rate, it affects economies and people's quality of life leading to public health emergency. Our country has interventions and policies for tackling air pollution issues that have been proven to be effective but a lot is yet to be done. In order to maximize the co-benefits of health, climate, environment, social and development the role of the health sector is crucial.

Urban air pollution depends on the emissions from point (industrial), line (road traffic) and area (trash burning, domestic etc.) sources. The more the level of activity, the more is the air pollution level. The higher emissions coupled with unfavourable weather conditions particularly in winter lead to high air pollution levels. On the other side if the activity level goes down, as is the case with the ongoing lockdown conditions, improved air quality has been observed. Our country is observing such a phenomenon due to spread of COVID-19 (novel Corona-Virus) transmission since March 25, 2020. However, the improvements in environmental quality are temporary due to short-term lockdown. Therefore the ground level observations of air quality in Lucknow are required to be monitored for establishing the scientific evidences for background air pollution levels of the region. A comprehensive approach will help in air pollution abatement and need based policy changes.

Currently, part of Lucknow city has been served by convenient metro system which has significant positive impact on city air pollution due to reduced road transportation along the metro corridor. Besides, recently constructed flyovers and express highways in and around the city also give a positive impact on air pollution levels. However, recently evolved city infrastructure usage is yet to reach the benchmark as desired. Further, rapid growth of population concentration and their activities and 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. The 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 24,07,190 as on 31.03.2020 which is 9.70% higher over the last year 2019. 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 31.03.2020 are given in Table 2. In Lucknow city there are 106 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 Companies (IOC, BPC and HPCL), the consumption/sale of petrol and diesel was 2,32,383 and 2,13,315 kL as on 31-03-2020. It is observed that petroleum sale has increased by 3.06% whereas sale of diesel has decreased by 3.00% (Table 4). In Lucknow there are nine CNG filling stations and consumption of CNG in the last year was approximately 4,23,59,025 kg (2019-20) which was 9.96% lower than the previous year (2018-19) (Green Gas Limited, Lucknow). Distribution and number of CNG vehicles in Lucknow are summarized in Table 5. The expansion of city is still continued, converting the land use from agricultural to residential/ commercial/ industrial. The increased fuel consumption in general have resulted in increased air pollution levels of the city.

This year, however, the scenario changed as the city was under lockdown since March 25th 2020. With the commencement of lockdown better air quality was observed by the masses. Therefore this year the study was conducted to assess the impact of lockdown on ambient air quality of Lucknow city at 8 locations during pre-monsoon

(March-May), 2020 with respect to PM_{10}, $PM_{2.5}$ SO_2, NO_2, trace metals (Pb and Ni) 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
		2018-19	2019-20	
1	Multi Articulated	5777	6144	6.35
2	Light, Medium and Heavy weight Vehicles (Four wheeler)	42318	47745	12.82
3	Light commercial vehicles (Three wheeler)	3482	3652	4.88
4	Buses	3876	4291	10.71
5	Omni Buses	489	489	0.00
6	Taxi	24851	30362	22.18
7	Light Motor Vehicles (Passenger)	8191	10157	24.00
8	Two wheelers	1708874	1804077	5.57
9	Motorcycle on hire	377	384	1.86
10	Car	297774	313597	5.31
11	Jeep	62398	85689	37.33
12	Tractor	26902	27136	0.87
13	Trailors	1946	1961	0.77
14	Others	7006	71506	920.64
Total		**21,94,261**	**24,07,190**	**9.70**

Source: RTO, Lucknow

Table 2
Details of Lucknow City Bus Service, 2020

S. No.	Route No.	To and Fro	No. of Buses	Frequency
1	101	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	11 minute interval
2	102	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.	06	18 minute interval
3	103	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.	09	12 minute interval
4	104	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.	04	21 minute interval
5	201	SGPGI Campus, SGPGI –Old Moyaia- Krishna viharcolony-Sardar Patel Dental College-Uttaria-Vindravan yajona-Awadth silpa Gram-Delhi Public school—Awadth Silpa Gram 2-CMS-Ahimamao-Criket stadium-DPS 2-Homeguard office—Hysadia- Gomti Nagar bus station-High court (Kamta).	03	28 minute interval

6	202	Industrial Area-Scooter India—Gouri vihar- Hindol colony-Sainik School-shanti nagar-Natherganj-Airport—bagia number- 3-Bagia Number-2-transport nagar- Auranga bad-Romabai Maidan-Shuvam south city-Uttaria-- Vindravan yajona-Awadth silpa Gram-Delhi Public school—Awadth Silpa Gram 2-CMS-Ahimamao-Criket stadium-DPS 2-Homeguard office—Husadia- Gomti Nagar bus station-High court (Kamta).	26	05 minute interval
7	301	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.	06	06 minute interval
8	302	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.	04	26 minute interval
9	402	P.S. Gudamba-Vikas nagar-Nishatganj-paper mill-Ghole Marg--Sikandarbagh- Jawahar Bhavan- Shakti Bhavan-GPO- Bapu Bhavan-Burlington- Hussainganj-Vikasdeep-KKC- Charbagh.-Mayaiba-Awadth hospital – PS Alambagh-Teri phulia-Bus stand-Ajanta- Alambagh chowraha-Ram nagar-Puran nagar-Singar Nagar-Awadh hospital-L.D.A. colony-Paskila chowraha-Rajanikhand.	10	11 minute interval
		Total	78	

Source: Lucknow City Transport Services Limited.

Table 3
Fuel Outlets in Lucknow City

S.No.	Agency	Number of outlets as on 31st March 2020
1	Indian Oil Corporation (IOC)	45
2	Bharat Petroleum Corporation Ltd. (BPCL)	24
3	Hindustan Petroleum Corporation Ltd. (HPCL)	28
4	Compressed Natural Gas Stations (CNG)	9
Total		**106**

*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 city

S. No.	Agency	Petrol in kL			High Speed Diesel in kL			CNG in kg		
		Apr. 18 to Mar. 19	Apr. 19 to Mar. 20	% Change	Apr. 18 to Mar. 19	Apr. 19 to Mar. 20	% Change	Apr. 18 to Mar. 19	Apr. 19 to Mar. 20	% Change
1	IOC	105486	102941	-2.41	86173	79421	-7.84	--	--	--
2	BPCL	63144	62793	-0.56	63457	49800	-21.52	--	--	--
3	HPCL	56848	66649	17.24	70284	84094	19.65	--	--	--
4	Green Gas	--		--	--		--	47044857	**42359025**	**-9.96**
Total		**225478**	**232383**	**3.06**	**219914**	**213315**	**-3.00**	**47044857**	**42359025**	**-9.96**

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

Table 5
Distribution of CNG Vehicles

S. No.	Vehicles	Number		% Change
		2018-19	2019-20	
1	Auto Rickshaws	4343	4343	--
2	Tempo Taxi	2575	2575	--
3	Buses (UPSRTC)	260	260	--
4	Buses (Private)	40	40	--
5	School Buses	1253	1557	24.26
6	School Van	1946	2231	14.65
7	Private Vehicles	205	472	130.24
8	Private Cars	11885	21168	78.11
	Total	**22,507**	**32,646**	**45.05**

Source: RTO, Lucknow, Green Gas Limited, Lucknow

1.2 MONITORING LOCATIONS AND METHODOLOGY

Air quality monitoring of pre-monsoon, 2020 coincides with the four national lockdown periods and air pollution monitoring was carried out at 8 locations in Lucknow over the lockdown periods. Seven sampling locations out of eight in the present study belong to the regular air quality monitoring spots in Lucknow since 1997, the remaining one being CSIR-IITR location, which is a commercial region. All the sampling locations of the season were selected based on the convenience to reach the sampling stations under the national lockdown restrictions. Table 6 illustrates the details of sampling period for respective locations during the four lockdown periods. Methodologies used for the analysis of samples for air pollutants are presented in Table 7.

Table 6
Monitoring Locations

S. No.	Location	Category
Lockdown-1: March 25 to April 14, 2020 and Lockdown-2: April 15 to May 03, 2020		
1	Aliganj	Residential
2	Indira Nagar	Residential
3	CSIR-IITR	Commercial cum traffic
4	Charbagh	Commercial cum traffic
Lockdown-3: May 04 to May 17, 2020		
1	Aliganj	Residential
2	Indira Nagar	Residential
3	CSIR-IITR	Commercial cum traffic
4	Charbagh	Commercial cum traffic
5	Alambagh	Commercial cum traffic
6	Amausi	Industrial
Lockdown-4: May 18 to May 31, 2020		
1	Aliganj	Residential
2	Indira Nagar	Residential
3	CSIR-IITR	Commercial cum traffic
4	Charbagh	Commercial cum traffic
5	Alambagh	Commercial cum traffic
6	Amausi	Industrial
7	Vikas Nagar	Residential
8	Gomti Nagar	Residential

Table 7
Parameters and Methodology for Air Quality Monitoring

S. No.	Parameters	Time Weighted Average	Methods of Measurement
1	Particulate Matter (PM_{10})	24 hours	Gravimetric
2	Fine 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 (Sodium-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 by Noise Level Meter during -daytime (6 AM to 10 PM) and -nighttime (10 PM to 6 AM)

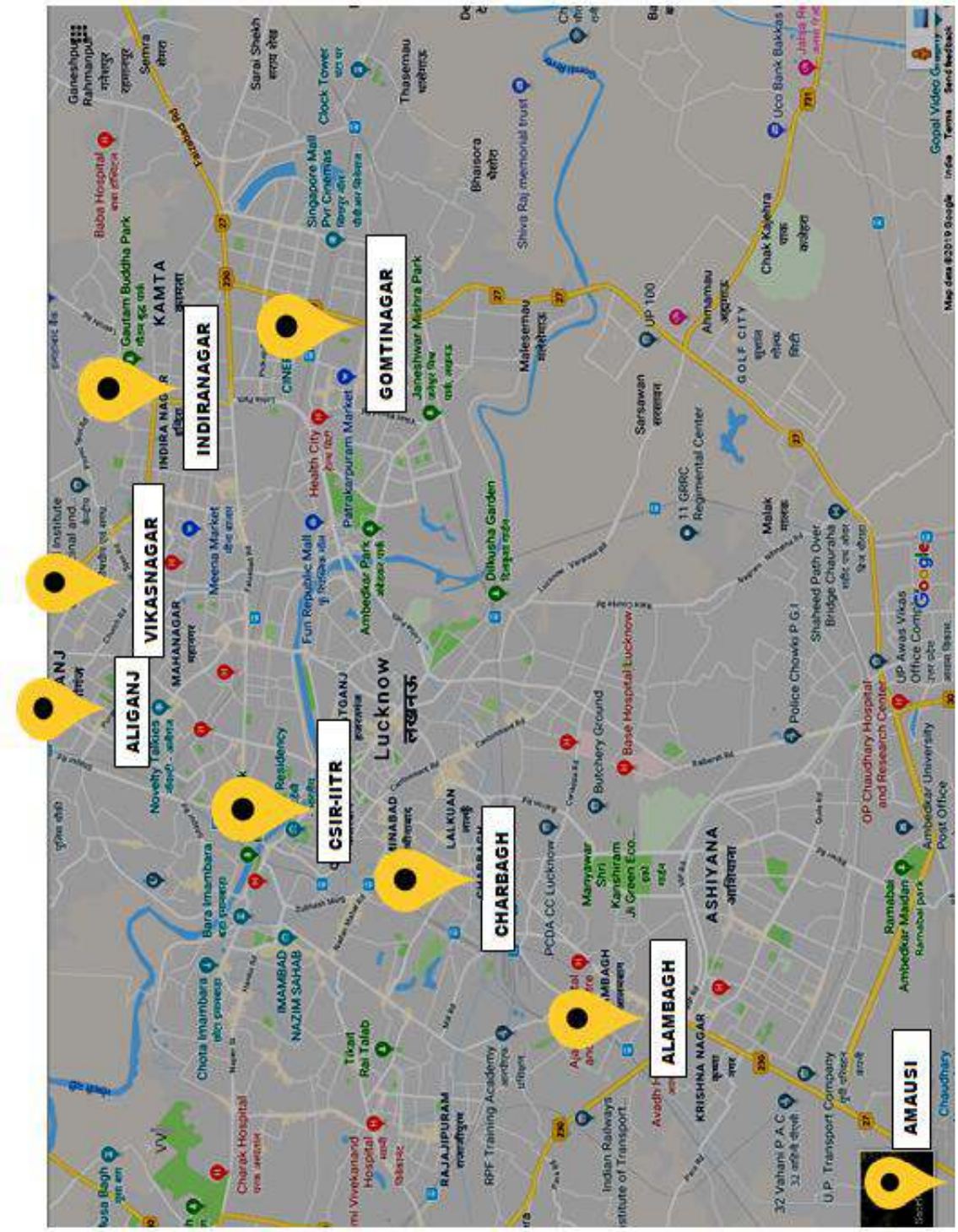


Figure 1: Ambient Air Pollution Monitoring Locations in Lucknow City

1.3 RESULTS

The detailed results of air quality monitoring are presented in Table 8 & 9 and Figure 2 to Figure 5.

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

The RSPM (PM_{10}) levels were found to be below the prescribed national standards during the first three consecutive lockdowns and exceeded marginally during the fourth lockdown period. The range of RSPM (PM_{10}) for the four consecutive lockdowns are 43.2 to 98.7, 50.6 to 115.5, 62.9 to 129.8 and 52.6 to 162.8 $\mu g/m^3$ respectively. Figure 2 presents the averages concentration of RSPM (PM_{10}) during the four lockdowns in Lucknow.

In residential areas (Aliganj, Vikas Nagar, Indira Nagar and Gomti Nagar), the 24 hours average concentrations of RSPM (PM_{10}) were in the range of 90.1 to 112.0 $\mu g/m^3$ with an average of 98.8 $\mu g/m^3$. In commercial areas (CSIR-IITR campus, Charbagh and Alambagh) the average concentrations of PM_{10} were in the range of 77.0 to 112.8 $\mu g/m^3$ with an average of 93.3 $\mu g/m^3$ respectively. In industrial area (Amausi), the average concentration of PM_{10} was 120.2 $\mu g/m^3$. The maximum 24 hours mean concentration of RSPM (PM_{10}) was observed in Vikas Nagar (112.0 $\mu g/m^3$) in residential areas and Alambagh (112.8 $\mu g/m^3$) in commercial areas. Figure 4 presents the location wise average RSPM (PM_{10}) levels of lockdowns in 2020, and its relative comparison with previous year concentration. There is a significant reduction of RSPM (PM_{10}) concentration in all the locations when compared with the same season of previous year 2019.

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

The $PM_{2.5}$ levels were found to be below the prescribed national standards during the first three consecutive lockdowns and exceeded marginally during the fourth lockdown period. The range of $PM_{2.5}$ for the four consecutive lockdowns are 21.7 to 69.7, 37.1to 75.5, 29.1 to 74.5 and 42.3 to 95.9 $\mu g/m^3$ respectively. Figure 2 presents

the averages concentration of $PM_{2.5}$ during the four lockdowns in Lucknow.

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 41.9 to 65.5 µg/m^3 with an average of 56.3 µg/m^3. In commercial areas (CSIR-IITR campus, Charbagh and Alambagh) the average concentrations of $PM_{2.5}$ were in the range of 43.6 to 61.2 µg/m^3 with an average of 54.8 µg/m^3 respectively. In industrial area (Amausi), the average concentration of $PM_{2.5}$ was 59.0 µg/m^3. The maximum 24 hours mean concentration of $PM_{2.5}$ was observed in Aliganj (65.5 µg/m^3) in residential areas and CSIR-IITR (61.2 µg/m^3) in commercial areas. Figure 4 presents the location wise average $PM_{2.5}$ levels of lockdowns in 2020, and its relative comparison with previous year concentration. There is a significant reduction of $PM_{2.5}$ concentration in all the locations when compared with the same season of previous year 2019.

1.3.3 Sulphur Dioxide (SO_2)

The SO_2 levels were found to be below the prescribed national standards during all the four lockdowns. The range of SO_2 for the four consecutive lockdowns are 3.4 to 7.4, 4.1 to 9.9, 4.2 to 9.4, and 2.5 to 12.6 µg/m^3 respectively. Figure 3 presents the averages concentration of SO_2 during the four lockdowns in Lucknow.

In residential areas (Aliganj, Vikas Nagar, Indira Nagar and Gomti Nagar), the 24 hours average concentrations of SO_2 were in the range of 5.0 to 5.8 µg/m^3 with an average of 5.4 µg/m^3. In commercial areas (CSIR-IITR campus, Charbagh and Alambagh) the average concentrations of SO_2 were in the range of 5.9 to 7.0 µg/m^3 with an average of 6.3 µg/m^3 respectively. In industrial area (Amausi), the average concentration of SO_2 was 7.0 µg/m^3. The maximum 24 hours mean concentration of SO_2 was observed in Indira Nagar (6.5 µg/m^3) in residential areas and Charbagh (7.0 µg/m^3) in commercial areas. Figure 5 presents the location wise average SO_2 levels of lockdowns in 2020, and its relative comparison with previous year concentration. There is a significant reduction of SO_2 concentration in all the locations when compared with the same season of previous year 2019.

1.3.4 Nitrogen Dioxide (NO_2)

The NO_2 levels were found to be below the prescribed national standards during all the consecutive lockdowns. The range of NO_2 for the four consecutive lockdowns are 14.2 to 5.0, 15.3 to 28.1, 16.8 to 5.7 and 16.1 to 55.9 µg/m^3 respectively. Figure 3 presents the average concentration of NO_2 during the four lockdowns in Lucknow.

In residential areas (Aliganj, Vikas Nagar, Indira Nagar and Gomti Nagar), the 24 hours average concentrations of NO_2 were in the range of 21.9 to 32.8 µg/m^3 with an average of 26.5 µg/m^3. In commercial areas (CSIR-IITR campus, Charbagh and Alambagh) the average concentrations of NO_2 were in the range of 20.5 to 30.8 µg/m^3 with an average of 26.6 µg/m^3 respectively. In industrial area (Amausi), the average concentration of NO_2 was 27.7 µg/m^3. The maximum 24 hours mean concentration of NO_2 was observed in Gomti Nagar (32.8 µg/m^3) in residential areas and CSIR-IITR (30.8 µg/m^3) in commercial areas. Figure 5 presents the location wise average NO_2 levels of lockdowns in 2020, and its relative comparison with previous year concentration. There is a significant reduction of NO_2 concentration in all the locations when compared with the same season of previous year 2019.

Table 8
Concentration (µg/m^3) of PM_{10}, $PM_{2.5}$, SO_2 and NO_2 during Pre-Monsoon 2020

Locations	PM_{10} (RSPM)			$PM_{2.5}$			SO_2			NO_2		
	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
Lockdown-1.0 (25th March to 14th April 2020)												
Aliganj	69.1	87.5	80.1	47.8	69.7	58.8	4.7	5.6	5.0	14.2	22.9	19.1
Indira Nagar	66.1	98.7	82.8	29.1	35.1	31.9	4.6	7.1	5.8	18.8	19.8	19.3
CSIR-IITR	54.2	95.0	76.4	33.8	68.1	56.9	4.1	6.6	5.2	17.8	25.0	20.6
Charbagh	43.2	94.6	60.6	21.7	58.8	31.7	3.4	7.4	5.6	16.3	19.0	17.7
Average			75.0			44.8			5.4			19.2
Lockdown-2.0 (15th April to 3rd May 2020)												
Aliganj	84.9	110.4	98.4	40.0	71.6	57.0	4.0	7.3	5.2	16.1	22.8	19.6
Indira Nagar	50.6	91.3	70.9	38.5	39.3	38.9	4.1	6.7	5.4	17.6	21.2	19.4
CSIR-IITR	74.3	115.5	96.1	37.1	75.5	58.9	4.1	8.4	6.6	16.3	28.1	22.3
Charbagh	71.9	109.8	87.8	38.7	66.1	52.5	4.2	9.9	6.9	15.3	22.4	19.9
Average			88.3			51.8			6.0			20.3
Lockdown-3.0 (4th May to 17th May 2020)												
Aliganj	75.5	129.8	105.5	51.1	74.5	65.5	4.8	6.6	5.5	21.8	42.2	31.1
Indira Nagar	92.8	97.3	95.0	42.1	49.0	45.6	5.2	6.7	5.9	27.0	29.0	28.0
CSIR-IITR	72.6	93.3	78.0	51.3	65.7	58.7	5.2	6.8	5.8	27.4	55.7	38.7
Charbagh	62.9	78.1	70.1	29.1	57.9	40.1	4.2	9.4	6.1	16.8	19.3	17.8
Alambagh	---	---	87.0	--	---	56.1	--	--	6.6	--	--	22.0
Amausi	69.4	107.9	88.6	54.6	58.1	56.4	6.2	7.2	6.7	26.1	34.5	30.3
Average			87.4			53.7			6.1			28.0
Lockdown-4.0 (18th May to 31st May 2020)												
Aliganj	81.2	148.3	114.5	68.9	95.7	84.5	5.3	6.6	6.0	30.2	44.0	35.7
Indira Nagar	119.0	131.5	126.0	46.7	60.8	54.8	4.8	11.8	8.2	18.0	26.1	21.3
Vikas Nagar	100.1	126.7	112.0	60.6	72.1	65.0	2.5	7.9	5.6	16.1	29.4	23.9
Gomti Nagar	52.6	111.5	83.7	42.3	68.0	51.5	3.6	6.2	5.1	24.4	35.9	34.2
CSIR-IITR	82.3	147.6	109.1	45.2	95.9	75.2	3.4	7.0	5.9	28.3	55.9	41.6
Charbagh	83.1	115.9	94.9	46.2	67.4	53.7	7.2	12.6	9.2	23.5	33.4	26.8
Alambagh	98.9	135.5	119.2	48.9	74.7	60.5	4.8	6.6	5.9	23.5	33.8	30.1
Amausi	105.4	162.8	136.0	48.7	80.2	60.3	4.8	9.1	7.1	18.1	36.5	26.3
Average			111.9			63.2			6.6			30.0
NAAQS	**100**			**60**			**80**			**80**		
WHO	**50**			**25**			**20**			**40***		

Total Number of samples (N) PM_{10} and $PM_{2.5}$ = 79, SO_2= 73, NO_2= 74 *= Annual Average, NAAQS=National Ambient Air Quality Standard, WHO= World Health Organization Guidelines

Table 9
Result Summary
Reduction in the mean levels of air pollutants from
Pre-Monsoon 2019 to Pre-Monsoon Lockdown 2020

Locations	PM_{10} (RSPM)			$PM_{2.5}$			SO_2			NO_2		
Residential												
	2019	**2020**	Change (%)	**2019**	**2020**	Change (%)	**2019**	**2020**	Change (%)	**2019**	**2020**	Change (%)
Aliganj	181.4	98.5	-45.7	85.1	65.5	-23.0	6.5	5.5	-15.4	36.2	27.4	-24.3
Vikas Nagar	185.7	112.0	-39.7	88.2	65.0	-26.3	7.2	5.6	-22.2	32.5	23.9	-26.5
Indira Nagar	170.7	94.7	-44.5	83.0	41.9	-49.5	7.1	6.5	-13.3	29.3	21.9	-25.3
Gomti Nagar	182.4	90.1	-50.6	84.3	52.8	-37.4	6.8	5.9	-13.8	37.9	32.8	-13.4
Commercial												
CSIR-IITR	ND	90.1	-	ND	61.2	-	ND	5.9	-	ND	30.8	-
Charbagh	190.9	77.0	-59.7	92.0	43.6	-52.6	10.3	7.0	-32.0	41.0	20.5	-50.0
Alambagh	180.1	112.8	-37.4	86.7	59.6	-31.2	7.8	6.0	-23.1	54.5	28.5	-47.7
Industrial												
Amausi	189.2	120.2	-36.5	79.8	59.0	-26.1	7.8	7.0	-10.3	29.8	27.7	-7.0
Mean	182.9	99.4	-44.9	85.6	56.1	-35.2	7.6	6.2	-17.9	37.3	26.7	-27.7

ND= Not Done

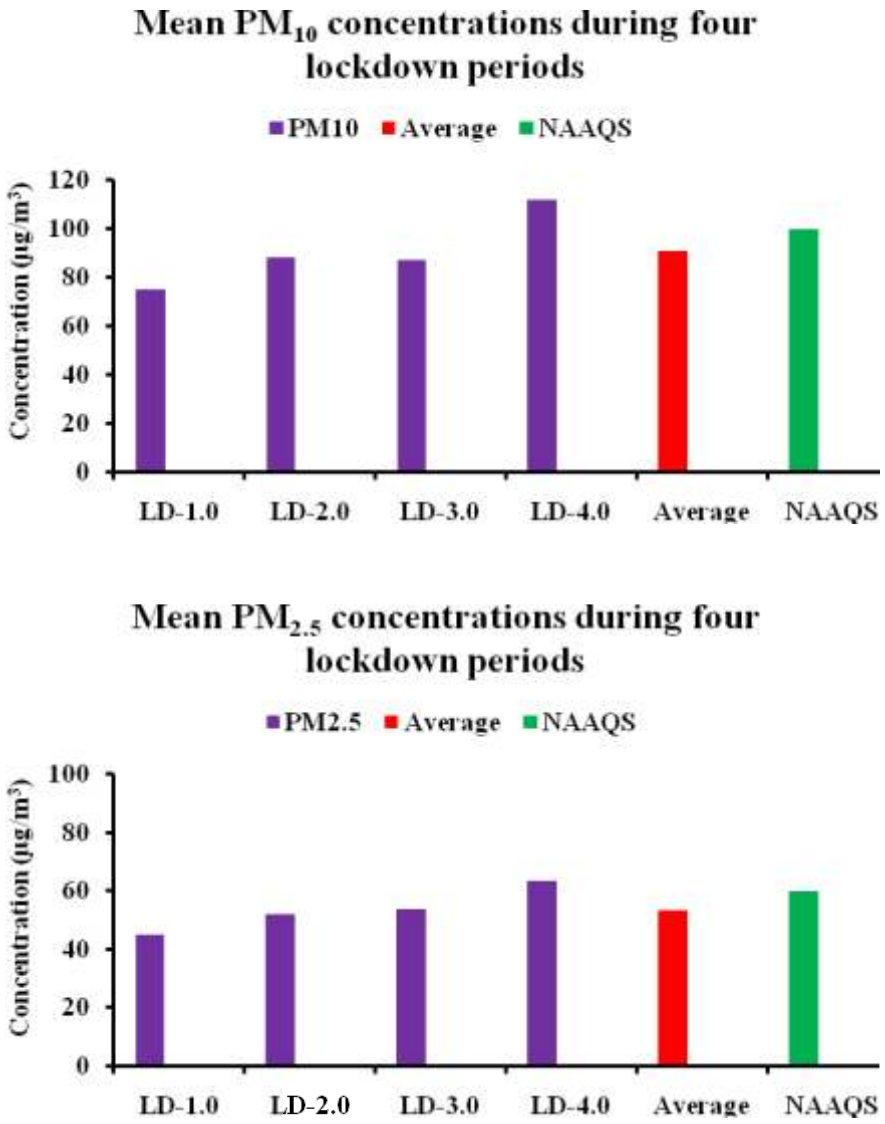


Figure 2: Concentration (µg/m^3) of PM_{10} and $PM_{2.5}$ during the four lockdown (LD) periods (pre-monsoon, 2020) in Lucknow city and compared with prescribed National Ambient Air Quality Standard (NAAQS)

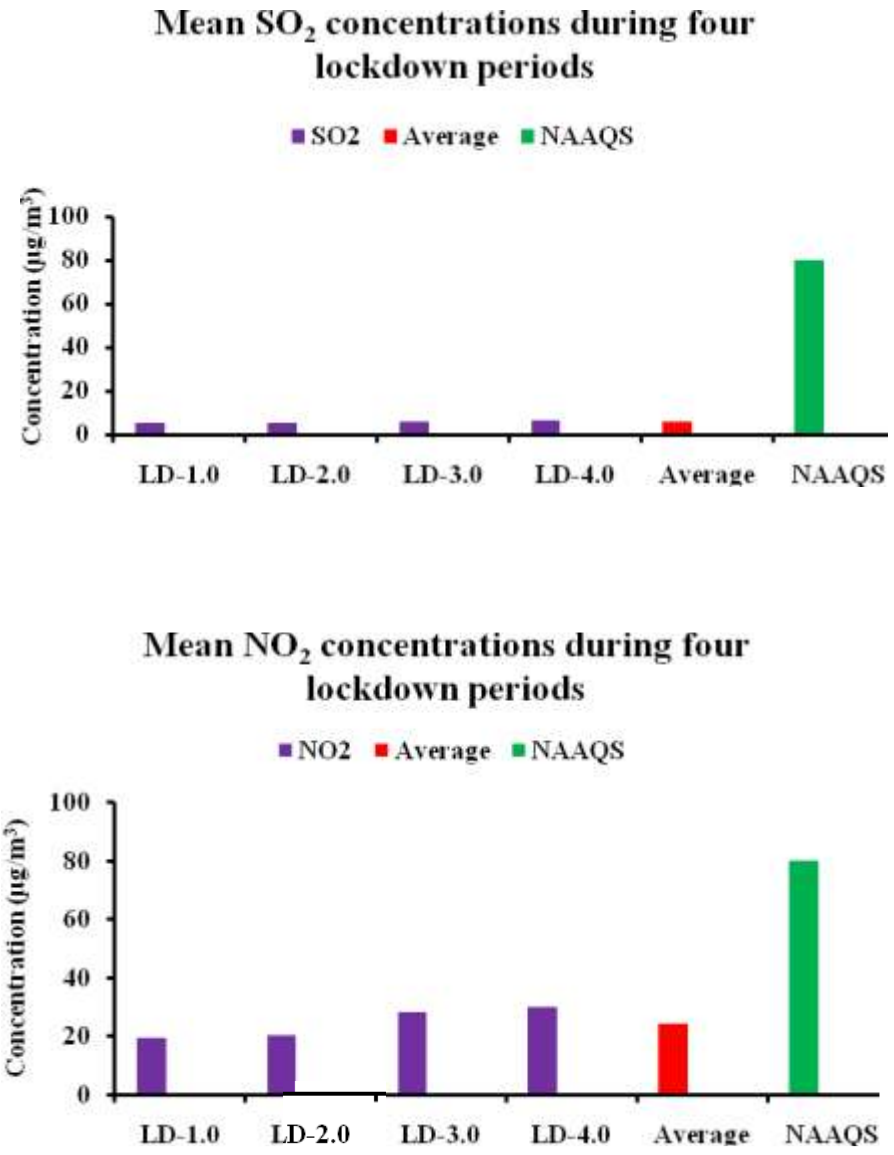
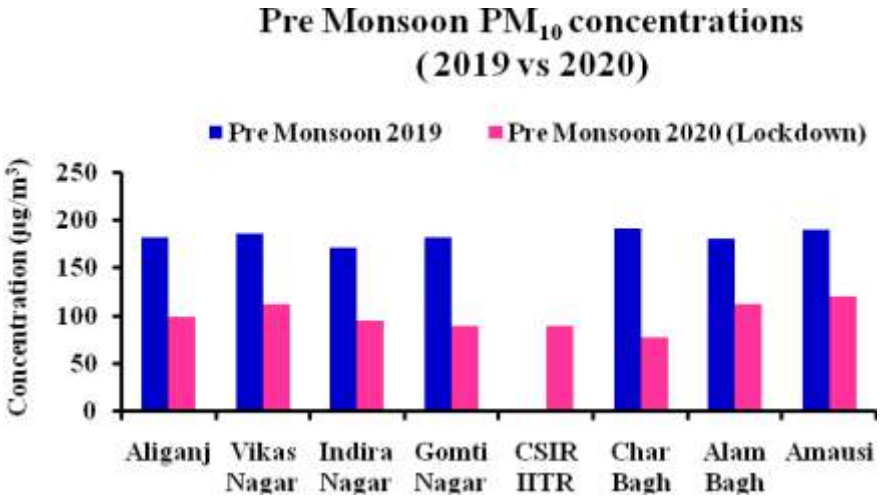


Figure 3: Concentration (µg/m^3) of SO_2 and NO_2 during the four lockdown (LD) periods (pre-monsoon, 2020) in Lucknow city and compared with prescribed National Ambient Air Quality Standard (NAAQS)



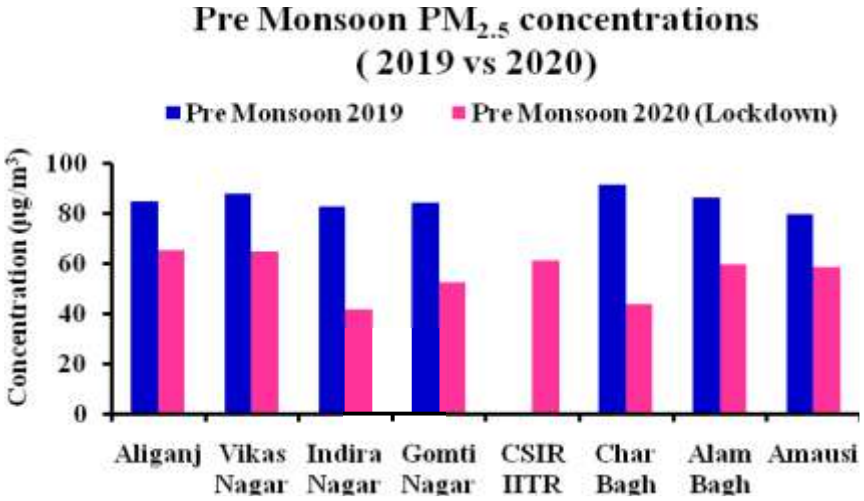


Figure 4: Comparison of PM_{10} and $PM_{2.5}$ levels ($\mu g/m^3$) at each location during normal days (Pre-Monsoon 2019) and during Lockdown periods (Pre-Monsoon 2020)

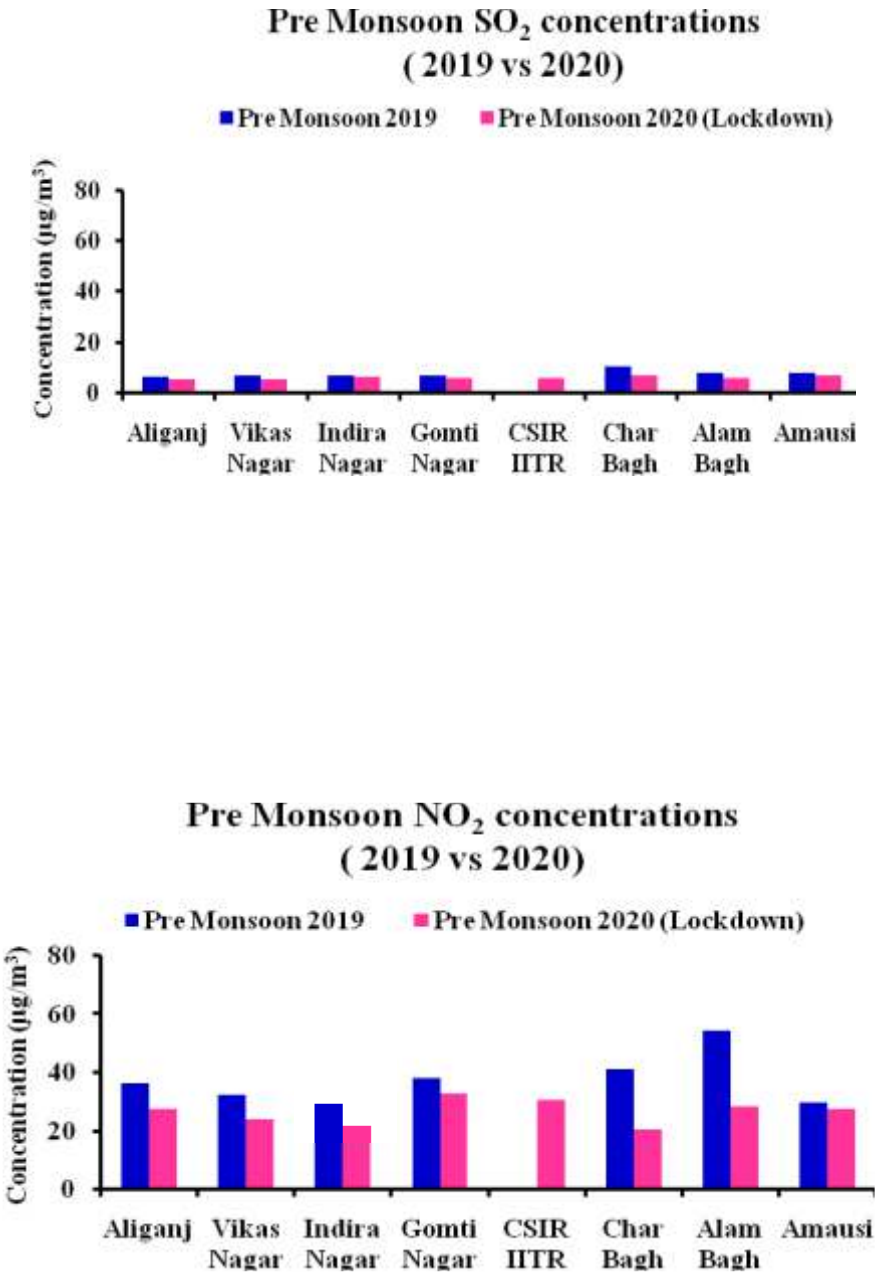


Figure 5: Comparison **of** SO_2 and NO_2 levels ($\mu g/m^3$) at each location during normal days (Pre-Monsoon 2019) and during Lockdown periods (Pre-Monsoon 2020)

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 8 monitoring locations. The results are presented in Table 10. The 24 hr mean concentration of metals were found to be Pb = 10.44 (6.05–17.33) ng/m^3 and Ni = 3.48 (2.03 – 6.36) ng/m^3 with reduction percentages of 70.38% for Pb and 26.69% for Ni over the previous year.

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

S. No.	Locations	Pb			Ni		
		2019	2020	Change (%)	2019	2020	Change (%)
1	Aliganj	24.74	6.05	-75.55	2.68	2.03	-24.25
2	Vikas Nagar	31.77	8.62	-72.87	2.47	4.05	63.97
3	Indira Nagar	14.49	9.65	-33.40	3.29	4.61	40.12
4	Gomti Nagar	27.91	17.33	-37.91	3.79	2.54	-32.98
5	CSIR-IITR	ND	10.22	--	ND	2.50	---
6	Charbagh	31.31	6.02	-80.77	16.95	6.36	-64.73
7	Alambagh	29.0	8.66	-70.14	1.6	2.28	42.50
8	Amausi	87.53	16.99	-80.59	2.41	3.43	42.32
Average		35.25	10.44	-70.38	4.74	3.48	-26.69
NAAQS		**1000**			**20***		

N= 1, *=Annual Average ND=Not Done

1.3.6 Noise Level

The noise monitoring data recorded during the pre-monsoon period (May, 2020) is presented in Table 11 and 12. In residential areas, the day time and night time noise levels were recorded during the month of May 2020 between 54.4 to 62.0 and 42.7 to 44.5 dB(A) respectively. While the daytime values (barring Gomti Nagar) were higher than the prescribed limits of 55 dB(A), nighttime values were lower than prescribed standard of 45 dB(A) respectively.

In commercial and traffic area, the day time noise levels were recorded during the month May 2020 between 60.1 to 68.3 dB(A). Noise level at all the commercial sites during day time were found to be above the prescribed limit of 65 dB(A) except for Alambagh, noise for which was within prescribed standards. Night time noise level of commercial area (Charbagh) was 47.8 dB (A) which was within the prescribed standard of 55 dB(A). In industrial area Amausi, the day time noise levels were recorded as 70.2 dB(A). Noise levels at industrial area was found to be within prescribed limits of 75.0 dB(A).

Table 11
Noise Level dB(A) during day time

S. No.	Area	Location	Noise level dB(A)		
			2019 (May)	2020 (May)	% Reduction
1	**Residential**	Aliganj	72.4	62.0	14.36
		Vikas Nagar	65.3	58.6	10.26
		Indira Nagar	66.0	60.2	8.79
		Gomti Nagar	72.7	54.4	25.17
		CPCB Standard	**55**		
2	**Commercial**	Charbagh	86.6	68.3	21.13
		Alambagh	67.2	60.1	10.56
		CSIR-IITR	--	65.1	--
		CPCB Standard	**65**		
3	**Industrial**	Amausi	76.2	70.2	7.87
		CPCB Standard	**75**		

Table 12
Noise Level dB (A) during Night Time

S. No.	Area	Locations	Noise level dB(A)		
			2019 (May)	2020 (May)	% Reduction
1	Residential	Aliganj	61.5	44.5	27.64
		Vikas Nagar	56.0	43.8	21.78
		Indira Nagar	62.9	42.7	32.11
		CPCB Standard	**45**		
2	Commercial	Charbagh	67.9	47.8	29.60
		CPCB Standard	**55**		

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 6-9). 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 significantly lower when compared to the data of the previous year, owing to lockdown conditions prevailing in the entire country. RSPM values were higher than the NAAQS only during LD-4.0 apart from Aliganj, where average concentration was seen to exceed NAAQS during LD-3.0 also. (Figure 6).

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. Values of the present study were found to be lower than the NAAQS during LD-1.0 and 2.0 and higher at most locations during LD-3.0 and LD-4.0. (Figure 7).

1.4.3 Sulphur dioxide (SO_2)

The level of SO_2 during pre-monsoon since 2016 is presented in Figure 8 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 8).

1.4.4 Oxides of Nitrogen (NO_2)

The level of NO_2 during pre monsoon since 2016 is presented in Figure 9 for all the locations. In residential, commercial and industrial areas, lower concentrations of NO_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 9).

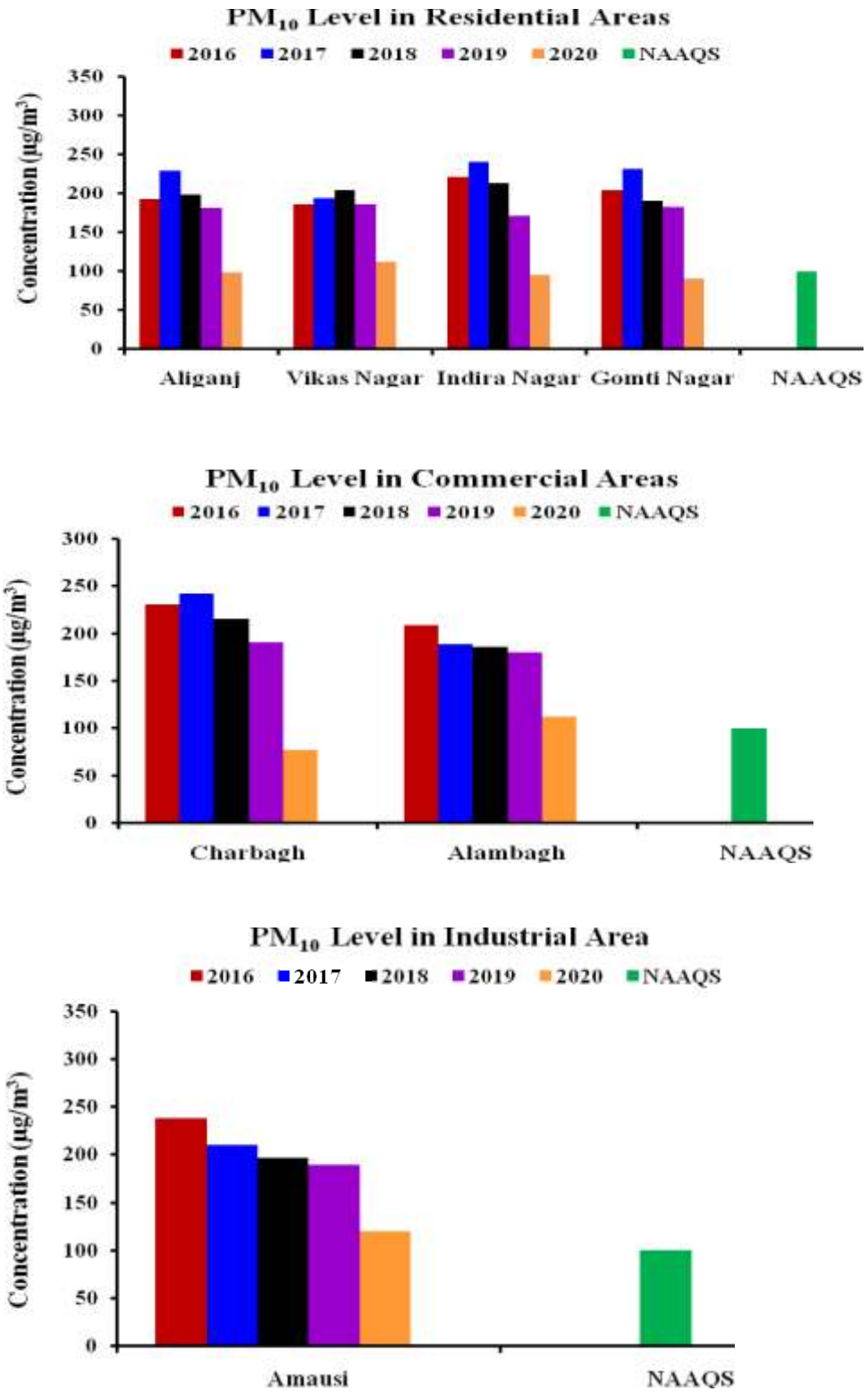


Figure 6: Concentration (µg/m^3) of PM_{10} **(**RSPM**)** in Residential, Commercial and Industrial areas of Lucknow city during 2016 to 2020 and compared with prescribed National Ambient Air Quality Standard (NAAQS)

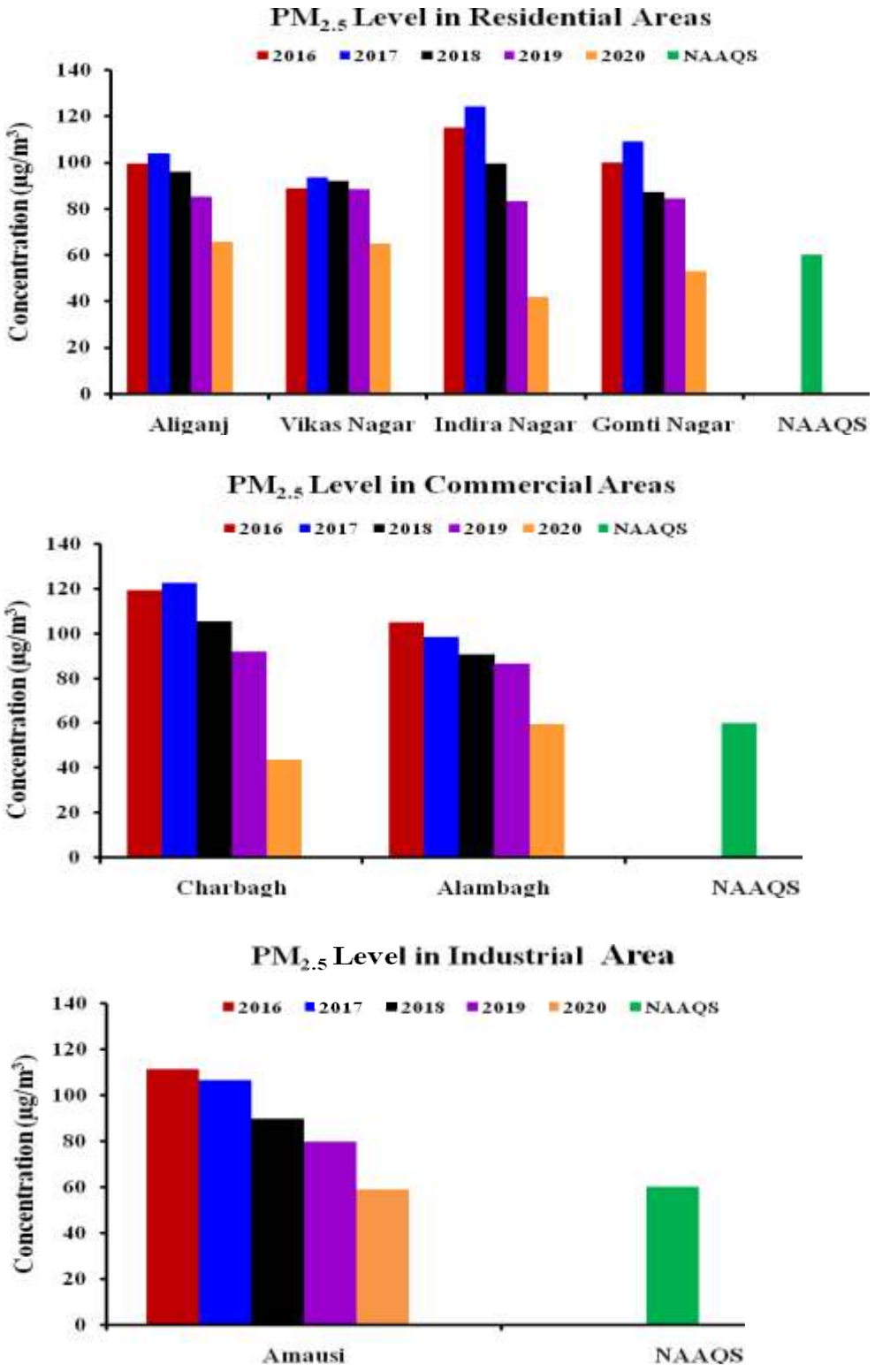


Figure 7: Concentration (µg/m^3) of $PM_{2.5}$ in Residential, Commercial and Industrial areas of Lucknow city during 2016 to 2020 and compared with prescribed National Ambient Air Quality Standard (NAAQS)

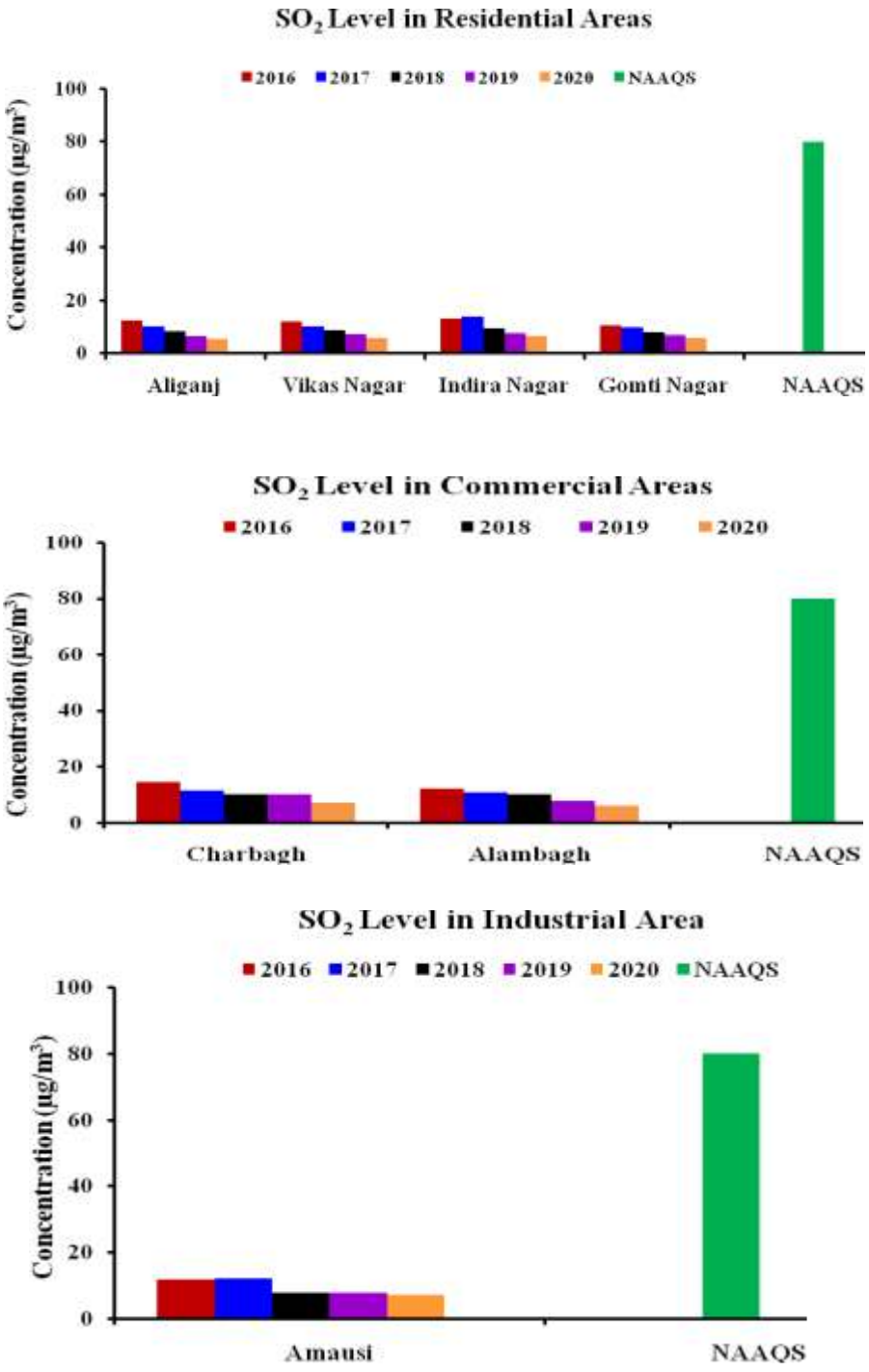


Figure 8: Concentration (µg/m^3) of SO_2 in Residential, Commercial and Industrial areas of Lucknow city during 2016 to 2020 and compared with prescribed National Ambient Air Quality Standard (NAAQS)

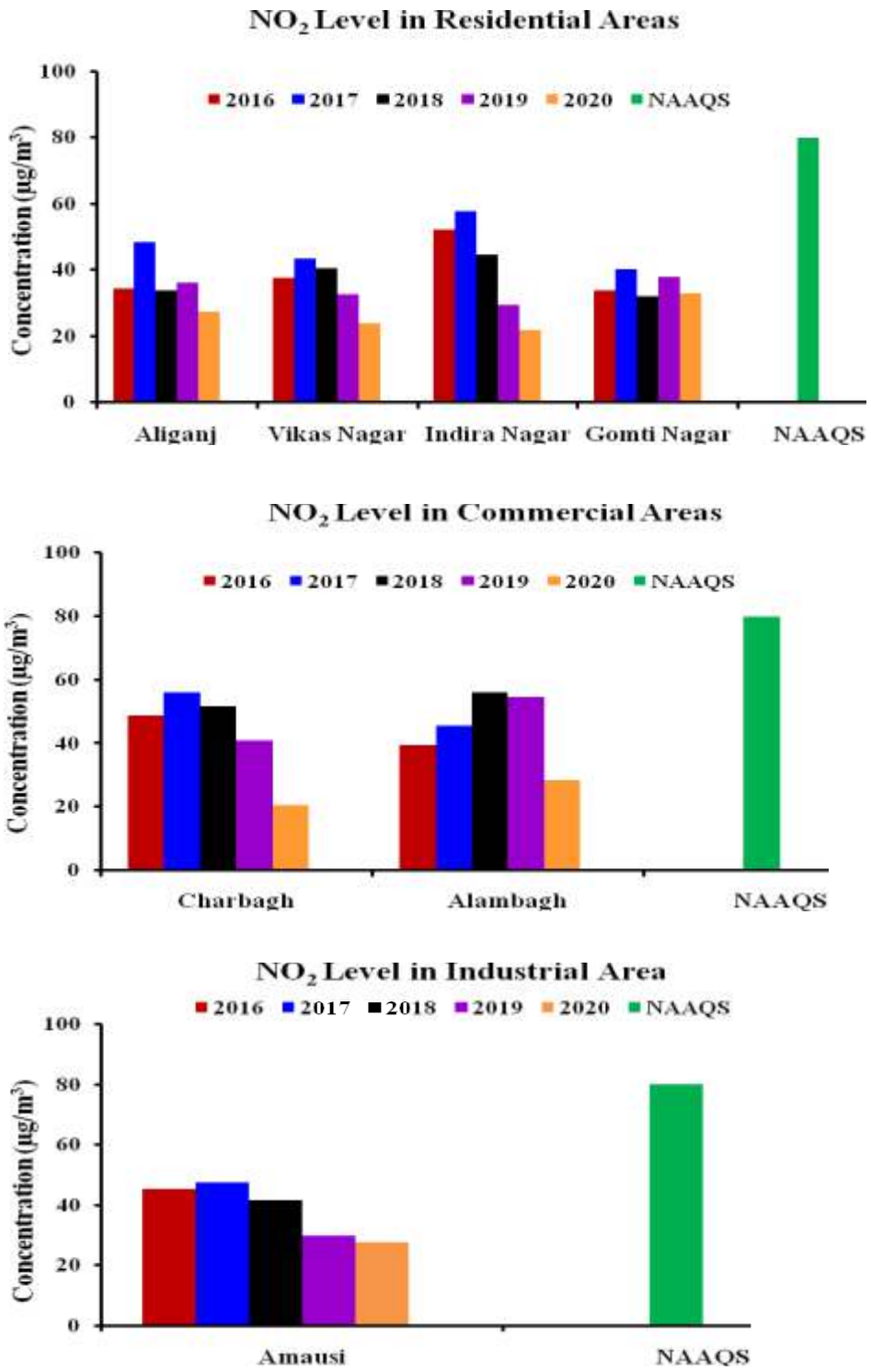


Figure 9: Concentration (µg/m^3) of NO_2 in Residential, Commercial and Industrial areas of Lucknow city during 2016 to 2020 and compared with prescribed National Ambient Air Quality Standard (NAAQS)

1.4.5 Lead (Pb)

The level of Pb during pre-monsoon since 2016 is presented in Figure 10 for all the locations. The concentrations show 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 2016 is presented in Figure 11 for all the locations. The concentrations show a decreasing trend at all the residential areas, commercial areas and also in industrial area.

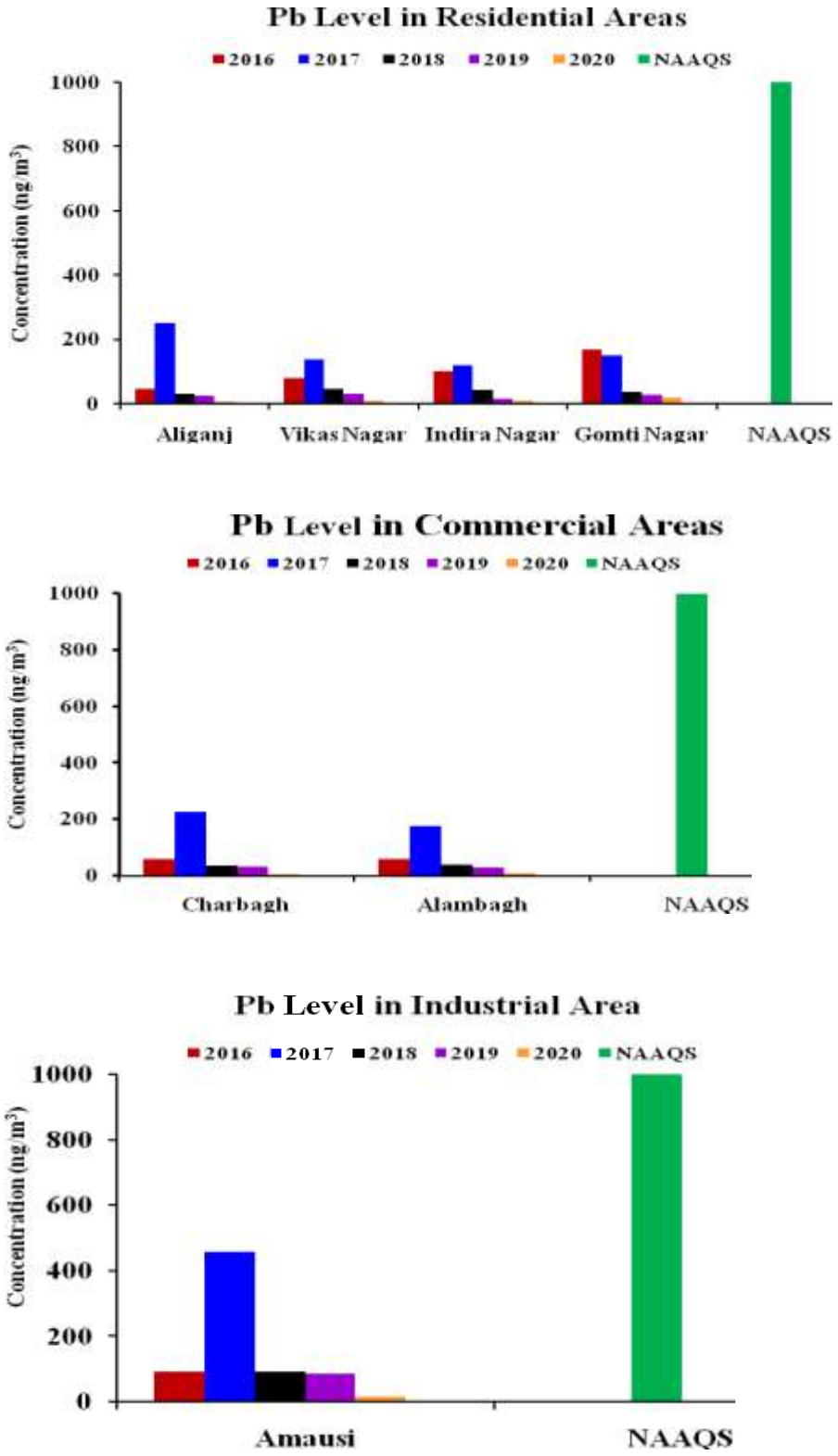


Figure 10: Concentration (ng/m^3) of Lead (Pb) in Residential, Commercial and Industrial areas of Lucknow city during 2016 to 2020 and compared with prescribed National Ambient Air Quality Standard (NAAQS)

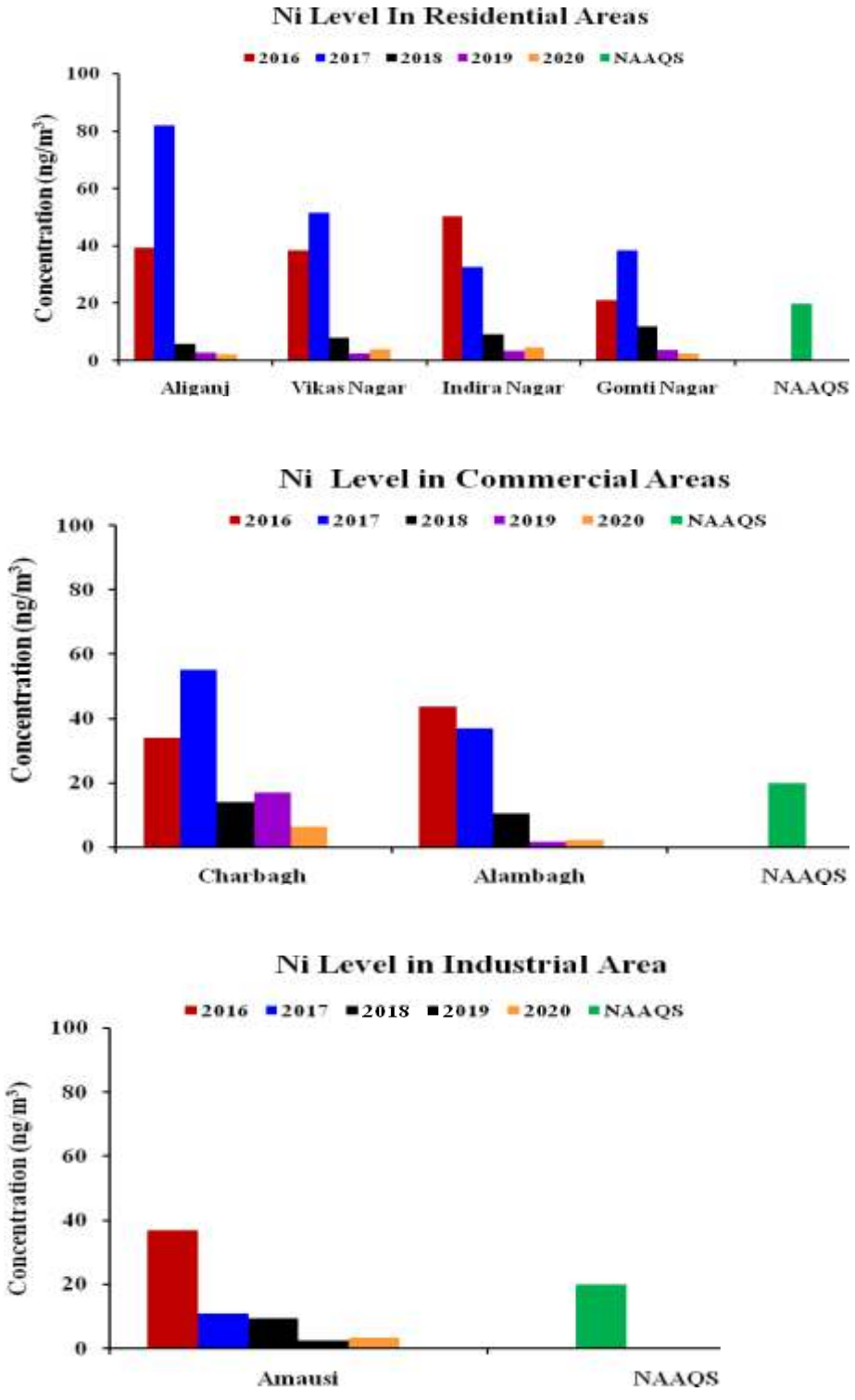


Figure 11: Concentration (ng/m^3) of Nickel (Ni) in Residential, Commercial and Industrial areas of Lucknow city during 2016 to 2020 and compared with prescribed Annual National Ambient Air Quality Standard (NAAQS)

1.4.7 Noise Level

Current year's noise data was compared with the corresponding data of the previous four years (2016 to 2020) and presented in Figure 12 and 13. The comparative noise levels in residential, commercial and industrial areas are described below:

1.4.7.1 Day time Noise Level

All the locations showed decreasing trend over that of the previous year. In residential and commercial cum traffic areas also noise levels were found to be on the lower side at all the locations compared to that of previous year. In industrial area (Amausi) noise level was slightly lower than that of the previous year. The comparative data are presented in Figure 12.

1.4.7.2 Night time Noise Level

Residential areas showed reduction in noise levels as compared to the previous year. In commercial area (Charbagh), the noise level was also recorded lower value as compared to previous year. Comparative data is shown in Figure 13.

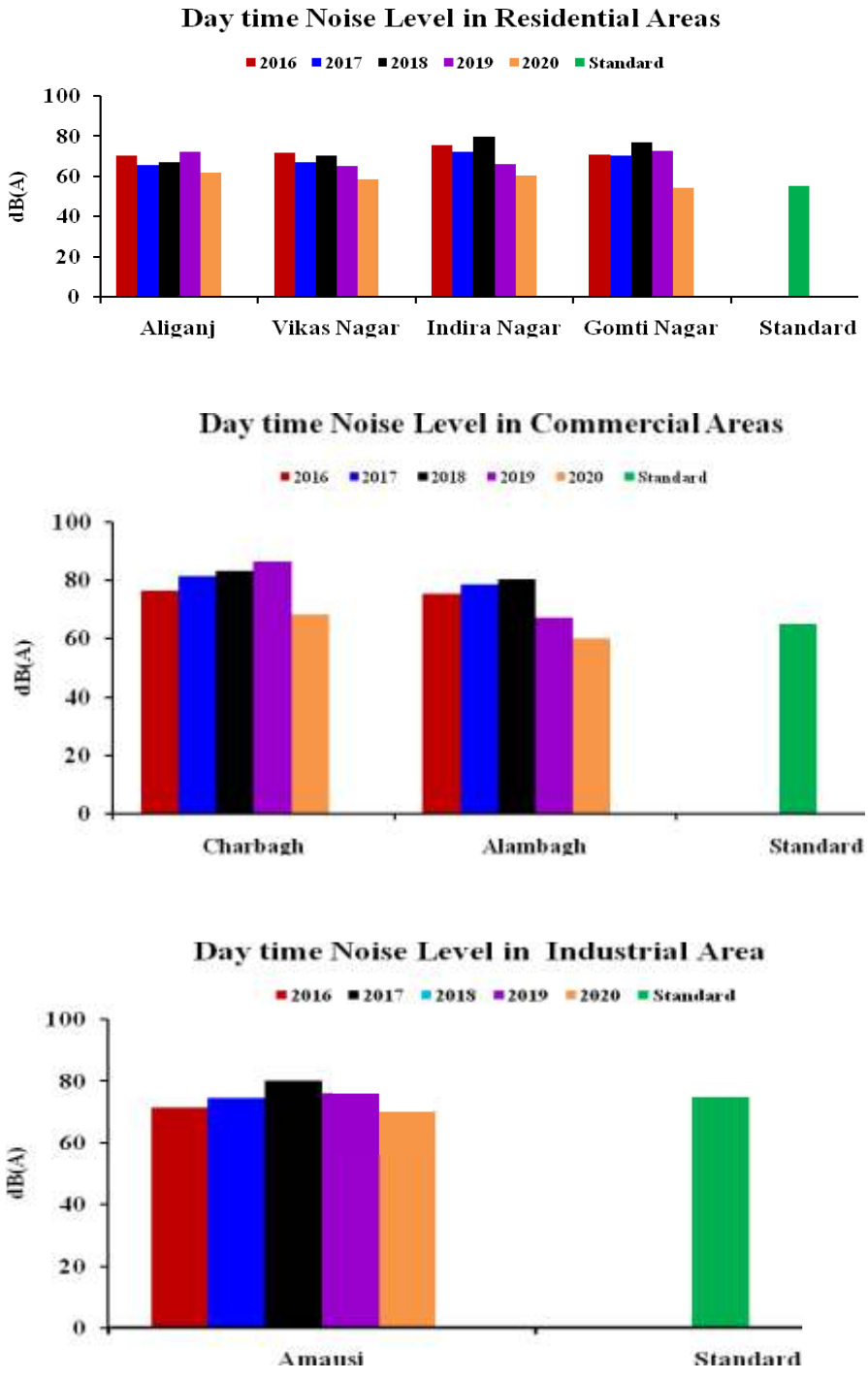
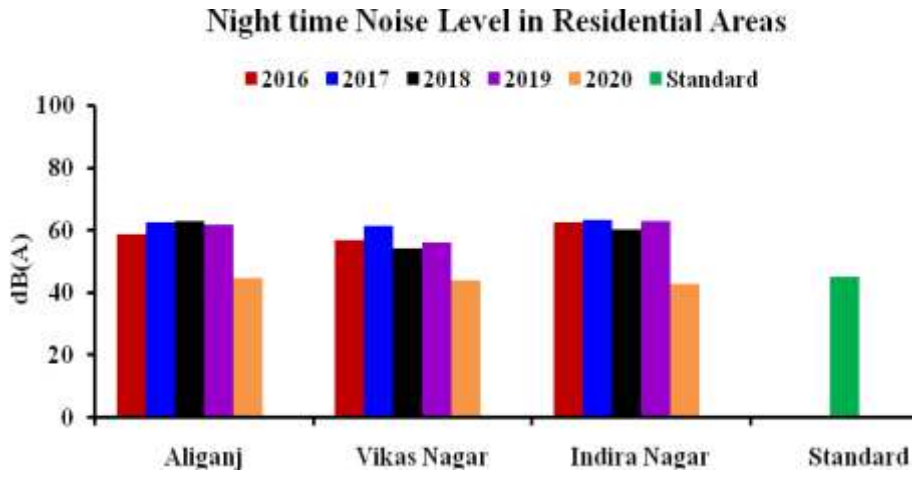


Figure 12: Comparison of day time Noise Levels dB(A) in different areas of Lucknow city (2016-2020)



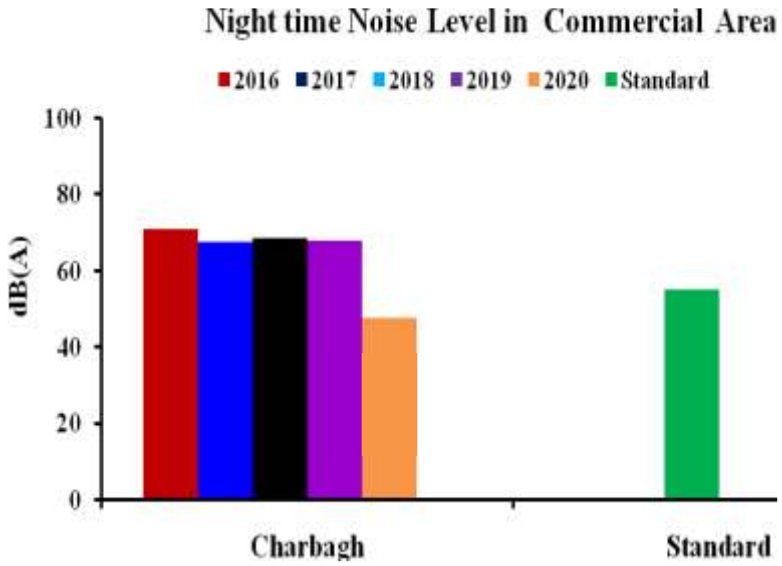


Figure 13: Comparison of night time Noise Levels dB (A) in different areas of Lucknow city (2016-2020)

1.5 HEALTH EFFECTS

Most cities have exceeded air pollution levels in India particularly with particle pollution which is observed to be above the national standards consistently. Air quality Index (AQI) has been used as indication for categorizing the air quality status of the different regions and reported as poor to severe in various cities. Exceeded air pollution levels impact human health and environment equally. Air pollution is causative of a 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 significantly affects visibility and leads to haze in the atmosphere as the particles in the air promote scattering and absorbtion of the light. Further, the resuspended particles remain suspended in the air, travelling 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 decrease of lung functioning.

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) cause 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.

Noise pollution affects vary from hearing loss to annoyance. Further, psychological damage would also occur at much lower noise levels.

Chronic exposure to the particle pollution (i.e. PM_{10}, $PM_{2.5}$ and smaller particles) leads to the increased mortality and morbidity in humans. However, the exact mechanism for

the toxicity of airborn particles is yet to be known. The degree of health effect depends on the physico-chemical composition of the ambient particulate matter and also on the level of associated trace metals, organic elements as well as the other pollutants. Overall, the toxicity depends on the some synergistic effects of particulate matter, environmental conditions, and receptor circumstances. For the current study Pb and Ni have been analyzed from the overall chemical composition, and the results are found to be within the prescribed limits.

The presence of inorganic elements are little in particle mass composition and particularly high level Pb concentration can induce severe neurological and hematological effects on the exposed people 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 of aerodynamic diameter ≤ 2.5 µm, when inhaled would penetrate beyond the larynx.
- Fine 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 cause fever induction.

1.5.2 Health Effects of Sulfur Dioxide (SO_2)

- SO_2 pollution in the ambient air 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 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)

- Inhaling of NO_2 pollution causes a wide variety of health and environmental impacts by various compounds in the group of NOx including NO_2, HNO_3, NO, nitrates and nitric oxide.
- Nitrogen dioxide (NO_2) is associated with mortality and morbidity outcomes.
- NO_2 is 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 induce development of acute or chronic bronchitis.
- Exposures to industrial nitric oxide emissions can cause unconsciousness, vomiting, mental confusion, and damage to the teeth.
- Exposure to even at low levels of nitrogen oxides in smog can irritate the eyes, nose, throat and lungs and can cause to cough, shortness of breath, fatigue, and nausea.

1.5.4 Health Effects of Trace elements

1.5.4.1 Lead (Pb)

- Lead is one of the neurotoxicant. It impairs of neurodevelopment in children, effects development of foetal brain.
- Occupational exposure to Pb increase mortality.
- Decreased nerve conduction velocity, impaired cognitive development and instinctual performance, hearing loss, jaundice, anemia in children are some detrimental impacts
- Cognitive and neurobehavioural deficits in children at low levels of exposure are of great concern.

1.5.4.2 Nickel (Ni)

- The harmful human health effects of nickel are 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.

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 impact to the eardrum leads 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.

Assessments of SO_2 and NO_2 levels for the present season were found to be below permissible limit of NAAQS. However, several studies reported that the gaseous pollutants are also cause for respiratory diseases and reproductive abberations. Vehicular traffic and NO_2 are associated with significantly higher risk of lung cancer.

1.6 CONCLUSIONS

Air pollution monitoring for PM_{10}, $PM_{2.5}$, SO_2, NO_2 and trace metals (Pb and Ni) was carried out during pre-monsoon (March – May), 2020 for the assessment of ambient air quality. Besides, noise levels were measured during the season at 8 locations. The highlights of results are as followed:

- The RSPM (PM_{10}) level at all the residential, commercial and industrial areas were found lower than the NAAQS during the first three phases of lockdown, but slightly higher during the fourth one.
- The average fine particles ($PM_{2.5}$) at all the residential, commercial and industrial areas were found lower than the NAAQS.
- The concentration of gaseous pollutants (i.e. SO_2 and NO_2) were found below the prescribed NAAQS (80 $\mu g/m^3$) at all the locations. However, the comparisons with the previous year, the gaseous pollutants were found significantly lower.
- The noise level at all the locations during day time showed higher level than their respective permissible limits but lower than the previous years.
- Overall results indicate that all the parameters monitored showed significantly lower levels than previous year due to consecutive lockdowns of the city.

Lockdown to prevent the spread of COVID-19 (novel Corona-Virus) transmission since March 25, 2020 coincides with CSIR-IITR air quality survey in Lucknow for pre-monsoon, 2020. The lockdown intervention restricted public gatherings, all modes of travel and lead to shutting-down of commercial and industrial activities. Along with the impact on economy and social life of the country, lockdowns were found to improve the air quality and visibility, owing to better mixing heights of the atmosphere as reported by media for most cities including Lucknow. However, the improvements in environmental quality are temporary due to the short-term lockdown which makes the continuous ground level monitoring of air quality in Lucknow imperative for establishing scientific evidences for background air pollution levels of the region. The study identified the difference in air quality at various locations in Lucknow from the current to previous year (non-lockdown period) and is therefore informative for public on the condition of city air quality and significantly supports the regulators for

establishing the new benchmarks for industries and automobiles to control the air emissions.

1.8 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 be installed at major traffic point which may be operated during peak hours.

Acknowledgements:

We acknowledge Analytical Chemistry Division., CSIR-IITR, for analytical and technical support. We express our sincere thanks to Mr R P Dwivedi, RTO, Mr. Sanjay Tiwari, ARTO (Administration) and Mr Sanjeev Kumar Gupta, ARTO (Enforcement), Mr PV. Shukla (DBA) Lucknow, Mr. Vinod Kumar, Assistant Regional Manager, Lucknow City Transport Services Limited, Gomti Nagar, Lucknow, Mr Mukesh Bharadwaj, Sr Manager, Retail sales, Indian Oil Corporation (IOC), Lucknow, Mr Pravir Mattu, Chief Manager, Business Planning (Retails), U.P., Bharat Petroleum Corporation Ltd (BPCL), Lucknow and Mr. Avinash Jain, Deputy General Manager, Hindustan Petroleum Corporation Limited (HPCL), Lucknow and Mr Surya Prakash Gupta, Chief Manager (Marketing), Green Gas Limited, Lucknow for providing us necessary vehicular and oil consumption data. We also express our sincere thanks to all who provided necessary facilities at different monitoring locations.

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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)

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