Assessment of Ambient Air Quality of Lucknow City

Post-Monsoon 2018

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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 31/03/2018**	:	20,08,190
❖ **Total No. of Filling Stations (Petrol/Diesel/CNG)**	:	110
❖ **Consumption of Petrol**	:	2,08,736 KL
❖ **Consumption of Diesel**	:	2,09,801 KL
❖ **Consumption of CNG**	:	4,24,37,108 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 POST-MONSOON, 2018

1.0 SUMMARY

This study was carried out during the month of September-October, 2018 to investigate the status of air quality by monitoring and assessment of some selected air pollutants namely Respirable Particulate Matter (RSPM or PM_{10}), Fine Particulate Matter ($PM_{2.5}$), Sulphur dioxide (SO_2), Nitrogen dioxide (NO_2) and noise level at 9 representative locations, categorized as residential (four), commercial (four) and industrial (one) areas in Lucknow city. The results revealed the 24 hours concentration of PM_{10} to be in the range of 101.2 to 291.4 µg/m^3 with an average of 213.8 µg/m^3, whereas 24 hours $PM_{2.5}$ level were found to be in the range 55.2 to 157.7 µg/m^3 with an average of 105.2 µg/m^3. The average values of PM_{10} and $PM_{2.5}$, irrespective of the locations were found to be above the permissible limit (PM_{10} =100 and $PM_{2.5}$ = 60 µg/m^3) prescribed by MoEF. Twenty four hours concentration of SO_2 and NO_2 were found in the range of 5.3 to 18.6 and 23.0 to 97.1 µg/m^{3}with an average concentration of 10.3 and 50.6 µg/m^3 respectively and all the mean values were below the permissible limits (80 µg/m^3). Trace metals Ni and Pb were found to be associated with PM_{10}. Twenty four hours concentration of Ni was found to be in the range of 8.35 to 44.25 with an average of 15.96 ng/m^3. The average Ni concentration was found to be below the permissible limit of annual average (20 ng/m^3). In case of Pb, 24 hours concentration in PM_{10} was found to be in the range of 76.02 to 241.38 with an average of 103.14 ng/m^3 which was within the permissible limit (1000 ng/m^3). Noise levels during day and night time were in the range of 66.3 to 71.9 dB(A) and 55.1 to 60.3 dB(A) respectively in residential area which were above the permissible limits (day time 55.0 and night time 45.0 dB(A)). The corresponding values of commercial area day time ranged between 70.2 to 79.3 dB(A) and night time 59.1 to 72.4 dB(A) exceeding the limits (day time 65.0 and night time 55.0 dB(A)). In industrial area recorded day time value, 76.4 dB(A) and night time 72.3 dB(A) was slightly higher than limits of 75.0 and 70.0 dB(A) during day and night time respectively.

1.1 INTRODUCTION

It may be hard to envisage the magnitude of ambient air pollution in an otherwise 'clean' looking area. This is so because in the generation of advanced technology the human race has reached crossroads between "visible and less harmful pollutants" and "practically invisible but gravely harmful pollutants". It is primarily a result of such concerns that ambient air quality monitoring programmes have picked up pace around the world and in India. The quality of ambient air is a complex entity defined not only by principal pollutants like particulate matter (encompassing PM_{10} and $PM_{2.5}$ and various sub-fractions), it includes various gaseous pollutants, organic pollutants like PAHs and various elements in conjunction with particulate matter as well. Besides the pollutants that are released from the source "as-such" and are referred to as primary pollutants, various processes in the atmosphere including micrometeorology affect the combination of various primary pollutants to sculpt a variety of secondary pollutants. Secondary pollutions are a bigger threat since neither are their precise origins known nor is their exact composition decipherable.

With reference to the Indian subcontinent, the post monsoon season is a period of festivity with the Durga Puja, Dusshera and Diwali festivals being celebrated in rapid succession. Burning of fire crackers during these festivals is foremostly responsible for the deteriorating air quality. Also, certain inherent changes in air quality owing to dipping night temperatures govern the formation of an inversion layer trapping pollutants near the ground level. Furthermore, since India derives its sustenance primarily from agriculture, the months of September and October are marked by preparations for the Rabi or winter season crop. Such preparations often include burning of agriculture residue from the previous cropping season producing a huge amount of smoke, dust and particulate matter which reaches adjoining cities. Therefore, this season observes high pollutant concentrations in most of the North Indian cities.

In the present context, not only is ambient air pollution seen as a grave concern to the environment, it is also a serious threat to human health. With air quality around the world declining rapidly inspite of constant efforts there is a rising consciousness about

the choices that we make to keep the air around us cleaner. Simultaneously air quality monitoring programmes are gaining importance since the environmentally aware lot of the population of any country prefer to remain abreast with the situation that they are facing or might face in the future. The matter is serious enough and is gradually becoming a primary concern among the government bodies and scientific community alike.

The sources of air pollution in urban areas include tail pipe emissions from vehicles, open air burning of municipal waste, exhaust gases from generator sets, roadside soil resuspension, operations of industrial units etc. Vehicular fuel consumption can be seen as the preliminary cause of worsening air quality and with both fuel utilization technologies and consumption patterns drifting from their norm, the composition of pollutants is also changing. The primary pollutants released include particulate matter, nitrogen oxides, oxides of sulphur, trace elements in conjunction with particulate matter, organic residues like PAHs etc. The changing scenario demands changed outlook towards air quality monitoring programmes and continuous monitoring of pollutants as well as their health effects.

In view of the above facts, it is the need of the hour to look into the air quality of our city Lucknow, the capital of Uttar Pradesh which has a population of 28.15 Lakh (Municipal Corporation + Cantonment) as per 2011 census and an area of 310 sq. km.

Vehicular traffic is the main source of particulate air pollution in Lucknow city. Continuous emission of pollutants from vehicular traffic adversely affects the ambient air quality as well as the health of human beings. The number of different categories of vehicles registered with RTO (Regional Transport Office) Lucknow was 20,08,190 on 31.03.2018 which is 1.51% higher over the last year (Table 1). Uttar Pradesh State Road Transport Corporation (UPSRTC) introduced bus services under the banner "Lucknow Mahanagar Parivahan Sewa" on different routes of Lucknow city. The details of bus routes and number of buses plying as on 31.03.2018 are given in Table 2. In Lucknow city there are 110 filling stations for petrol, diesel and CNG operated by different oil companies (Table 3).

As per Oil Marketing Company [Indian Oil Corporation (IOC), Bharat Petroleum Corporation Limited (BPCL), Hindustan Petroleum Corporation (HPCL)] the consumption/ sale of petrol and diesel were 2,08,736 and 2,09,801 KL as on 31-03-2018. It is observed that petroleum sale has increased by 7.96% whereas sale of diesel has decreased by 9.03% (Table 4). In Lucknow, there are six CNG filling stations and consumption of CNG during the last year was approximately 4,24,37,108 kg (2017-18) which was 32.06% higher than the previous year (2016-17) (Green Gas Limited, Lucknow). Distribution and number of CNG vehicles in Lucknow city is summarized in Table 5. Considering the above, assessment of ambient air quality of Lucknow city was carried out at 9 locations during post monsoon (September-October), 2018 with respect to PM_{10}, $PM_{2.5}$, SO_2, NO_2 and Noise level with the following aims and objectives:

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

Table 1

Comparison of Vehicular Population in Lucknow

S.No.	Type of Vehicle	Number of Registered Vehicles as on 31st March		% Change
		2016-17	2017-18	
1	Multi Articulated	3556	4379	23.14
2	Light, Medium and Heavy weight Vehicles (Four wheeler)	26225	29454	12.31
3	Light commercial vehicles (Three wheeler)	3408	3601	5.66
4	Buses	3324	3538	6.44
5	Taxi	10003	17554	75.49
6	Light Motor Vehicles (Passenger)	7606	7929	4.25
7	Two wheelers	1582255	1590913*	0.55*
8	Car	274853	278938	1.49
9	Jeep	35592	37863	6.38
10	Tractor	24919	25309	1.57
11	Trailors	1727	1858	7.59
12	Others	4877	6854	40.54
Total		**19,78,345**	**20,08,190***	**1.51***

Source: RTO, Lucknow,

** Figures are under review*

Table 2
Details of Lucknow City Bus Service, 2018

S. No	Route No.	To and Fro	No. of Buses	Frequency
1	11	BBD – Chinhat - Gomti Nagar - Alambagh Malhaur Railway Station - Gomti Nagar - Dalibagh - Charbagh Charbagh - Alambagh - Avadh Hospital - SGPGI Charbagh - Alambagh - Sardar Patel Dental College BBD - Chinhat - Awadh Hospital Charbagh - Alambagh - BBAU Charbagh - Alambagh - Gopesh Kunj - Kalindi Park Khargapur - Patrakarpuram - Alambagh	12	15 minute interval
2	12	Barabanki - Safedabad Crossing - Ramswarup College - Tewariganj -BBD - Chinhat - HAL Nishatganj - Sikindrabad - KKC College - Charbagh	29	15 minute interval
3	12 D	Charbagh – KKC- Vikas Deep-Husainganj-Burlington—Bapu Bhawan- GPO-Shakti Bhawan- Sikanderbagh- Dainik Jagaran-Trikonia Park- FUN Republic-Lohia park-BB D Academy-CMS- Vishal Khand—PS Gomtinagar-Chinhat More-matiaretoraha-mati-DEVA.	11	30 minute interval
4	23	Integral University-Gudamba-Vikasnagar– Nishatganj - Sikandrabad - Hussainganj - Alambagh - Avadh Hospital - Rajnikhand	15	15 minute interval
5	23 SU	Integral University-Gudamba-Vikasnagar– Nishatganj –Paper mill-Ghole Marg- Sikandrabad Income tax Bhawan- GPO-Hussainganj - Alambagh - Avadh Hospital –R.T.O- Kamta Chowraha.	01	180 minute interval
6	31	IM Sector Q-Beligaradh-PNT-Purania-Kapoorthala-ChanniLaL - Mahanagar -Gole market - Badhshanagar - Nishatganj –G.P.O-Hussainganj - Charbagh	02	60 minute interval
7	31 A	Airforce-Bakshi-ka-Talab- Engineering College-Purania – Regional Science Centre-Kapporthala-Channilal-Mahanagar-Gole Market-Badshanagar-Nishaganj-Paper Mill-Ghole marg-Sikandarbagh-GPO-Bapu Bhawan-Hussainganj- Lal Kouaa-Charbagh.	1	120 minute interval
	33	Engineering College – Purania – Kapporthala- Gole market-Sikandrabadh-GPO-Charbagh - Alambagh - Scooter India	06	30 minute interval
9	33 C	Bhitoli - CDRI Chowraha - Jankipuram - Purania - Mahanagar - Badshahnagar - Nishatganj - Hussainganj - Charbagh - Alambagh Cowraha.	05	15 minute interval
10	33 S	Bhitoli Chowraha - Engineering College – Kapoorthala - Badshahnagar – Nishatganj – Hussainganj – Charbagh – Alambagh -Bhudeswar Chowraha - Dr. Sukuntala Mishra University.	1	180 minute interval
11	33 SU	Engineering Collete-Purania- Kapporthala-Gole Market-Badshahnagar-Nishatganj-Sikandarbagh—GPO- Alamhagh-RTO-Kamta Chowraha	01	180 minute interval
12	33 PGI	Charbagh-Sadar More-Command hospital-Telibagh-PGI-Mohanlalganj.	06	15 minute interval

13	43H	New High Court- -Polytechnic Chowraha- Munshiphulia-Khuramnagar Chowraha-Jagrani Chowraha-Teriphulia-Dubagga Chowraha	02	60 minute interval
14	45	Virajkhand – indira Prathisthan –Politechnic-HA.L.-Badshahnagar- Nishatganj-G.P.P.- Hussainganj- Charbagh - Alambagh - Paasi Kila -Aurangabad - Shahid path	12	15 minute interval
15	48.B	Kesarbagh-Bapubhawan-Chief minister house-Lohia Chowraha-Polytechnic-Aahimou-Khurdahi Bazar-Gosainganj-Haidergarh	02	120 minute interval
16	500 S	Raja Suchana Aayog-Kamta Chowraha-Aahimau-Uttaria-PGI-Mohanlalganj-Sisandhi	01	120 minute interval
		Total	**107**	

Source: Lucknow City Transport Services Limited.

Table 3
Fuel Outlets in Lucknow City

S.No.	Agency	Number of outlets as on 31st March 2018
1	Indian Oil Corporation (IOC)	41
2	Bharat Petroleum Corporation Ltd. (BPCL)	32
3	Hindustan Petroleum Corporation Ltd. (HPCL)	28
4	Compressed Natural Gas Stations (CNG)*	9
Total		**110**

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

Table 4
Consumption of Fuel in Lucknow

S.No.	Agency	Petrol in KL			High Speed Diesel in KL			CNG in Kg		
		Apr. 16 to Mar. 17	Apr. 17 to Mar. 18	% Change	Apr. 16 to Mar. 17	Apr. 17 to Mar. 18	% Change	Apr. 16 to Mar. 17	Apr. 17 to Mar. 18	% Change
1	**IOC**	103065	105428	2.29	91101	88648	-2.69	--	--	--
2	**BPCL**	54630	49115	-10.09	55655	54533	-2.02	---	--	--
3	**HPCL**	35650	54193	52.01	83870	66620	-20.57	---	--	--
4	**Green Gas**	--		--	--	--		32134736	42437108	32.06
Total		**193345**	**208736**	**7.96**	**230626**	**209801**	**-9.03**	**32134736**	**42437108**	**32.06**

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
		2016-17	2017-18	
1	Auto Rickshaws	4343	4343	--
2	Tempo Taxi	2575	2575	--
3	Buses (UPSRTC)	260	260	--
4	Buses (Private)	40	40	--
5	School Buses	1201	1237	2.99
6	School Van	1731	1914	10.57
7	Private Vehicles	205	205	--
8	Private Cars	10851	11575	6.67
Total		**21,206**	**22,149**	**4.45**

Source: RTO, Lucknow

1.2 MONITORING LOCATIONS AND METHODOLOGY

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

Table 7
Parameters and Methodology for Air Quality Monitoring

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

1.3 RESULTS

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

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

In residential areas (Aliganj, Vikas Nagar, Indira Nagar and Gomti Nagar), the 24 hours average concentrations of PM_{10} were in the range of 196.5 to 226.8 µg/m^3 with an average of 208.2 µg/m^3. In commercial areas (Charbagh, Alambagh, Aminabad and Chowk) the average concentrations of PM_{10} were in the range of 189.0 to 224.8 µg/m^3 with an average of 210.0 µg/m^3 respectively. In industrial area (Amausi), the average concentration of PM_{10} was 223.3 µg/m^3.

Maximum 24 hours mean concentration of PM_{10} was observed in Indira Nagar (226.8 µg/m^3) in residential area and Alambagh (224.8 µg/m^3) in commercial area. Overall, at all the locations, mean values of PM_{10} were above the prescribed National Ambient Air Quality Standard (NAAQS) of 100 µg/m^3 for industrial, residential, rural and other areas.

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

In residential areas (Aliganj, Vikas Nagar, Indira Nagar and Gomti Nagar), the 24 hours average concentrations of $PM_{2.5}$ were in the range of 96.8 to 107.8 µg/m^3 with an average of 103.2 µg/m^3. In commercial areas (Charbagh, Alambagh, Aminabad and Chowk), the average concentrations of $PM_{2.5}$ were in the range of 91.7 to 116.8 µg/m^3 with an average of 104.8 µg/m^3 respectively. In industrial area (Amausi), the average concentrations of $PM_{2.5}$ were 107.7 µg/m^3.

The maximum 24 hours mean concentration of $PM_{2.5}$ was observed in Indira Nagar (107.8 µg/m^3) in residential area and Charbagh (116.8 µg/m^3) in commercial area. Over all at all the locations mean values of $PM_{2.5}$ were above the prescribed National Ambient Air Quality Standard (NAAQS) of 60 µg/m^3 for industrial, residential, rural and other area.

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 9.4 to 12.0 µg/m^3 with an average of 10.6 µg/m^3. In commercial areas (Charbagh, Alambagh, Aminabad and Chowk), the average concentrations of SO_2 were in the range of 9.2 to 11.7 µg/m^3 with an average of 10.8 µg/m^3. In industrial area (Amausi) the average concentration of SO_2 was 9.5 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 39.7 to 54.8 µg/m^3 with an average of 44.2 µg/m^3. In commercial areas (Charbagh, Alambagh, Aminabad and Chowk), the average concentrations of NO_2 were found in the range of 49.5 to 64.6 µg/m^3 with an average of 57.1 µg/m^3. In industrial area (Amausi) the average concentration was 50.0 µg/m^3. All the mean values of NO_2 were within the prescribed NAAQS of 80 µg/m^3 for all the monitoring locations.

Table 8

Concentration of PM_{10}, $PM_{2.5}$, SO_2 and NO_2 during Post Monsoon, 2018 (28^{th} September to 26^{th} October 2018)

	PM_{10} (RSPM) ($\mu g/m^3$)			$PM_{2.5}$ ($\mu g/m^3$)			SO_2 ($\mu g/m^3$)			NO_2 ($\mu g/m^3$)		
Residential												
	Min.	**Max.**	**Avg.**	**Min.**	**Max.**	**Avg.**	**Min.**	**Max.**	**Avg.**	**Min.**	**Max.**	**Avg.**
Aliganj	128.4	265.6	**202.4**	70.3	128.7	**102.5**	5.6	15.9	**9.4**	25.0	66.1	**41.6**
Vikas Nagar	101.2	274.3	**207.1**	55.2	142.1	**105.5**	6.7	14.8	**10.6**	23.0	64.5	**40.7**
Indira Nagar	121.4	291.4	**226.8**	57.0	157.7	**107.8**	8.4	15.8	**12.0**	34.9	76.8	**54.8**
Gomti Nagar	132.7	253.6	**196.5**	56.4	123.6	**96.8**	6.3	17.7	**10.4**	29.1	53.9	**39.7**
Commercial												
Charbagh	139.3	277.7	**219.1**	74.0	149.8	**116.8**	8.4	17.3	**11.6**	29.4	64.2	**49.5**
Alambagh	157.4	276.5	**224.8**	72.8	137.2	**108.1**	6.5	18.6	**11.7**	45.6	96.1	**64.6**
Aminabad	112.9	252.3	**189.0**	70.3	121.9	**91.7**	5.3	16.7	**10.5**	32.7	97.1	**54.9**
Chowk	147.9	250.5	**206.4**	60.9	135.8	**102.2**	6.6	10.6	**9.2**	32.8	93.8	**59.2**
Industrial												
Amausi	124.7	266.6	**223.3**	56.1	138.6	**107.7**	6.2	12.9	**9.5**	27.2	84.8	**50.5**
NAAQS	**100**			**60**			**80**			**80**		
WHO Guidelines	**50**			**25**			**20***			**40***		

N=7, *= Annual average, NAAQS=National Ambient Air Quality Standard

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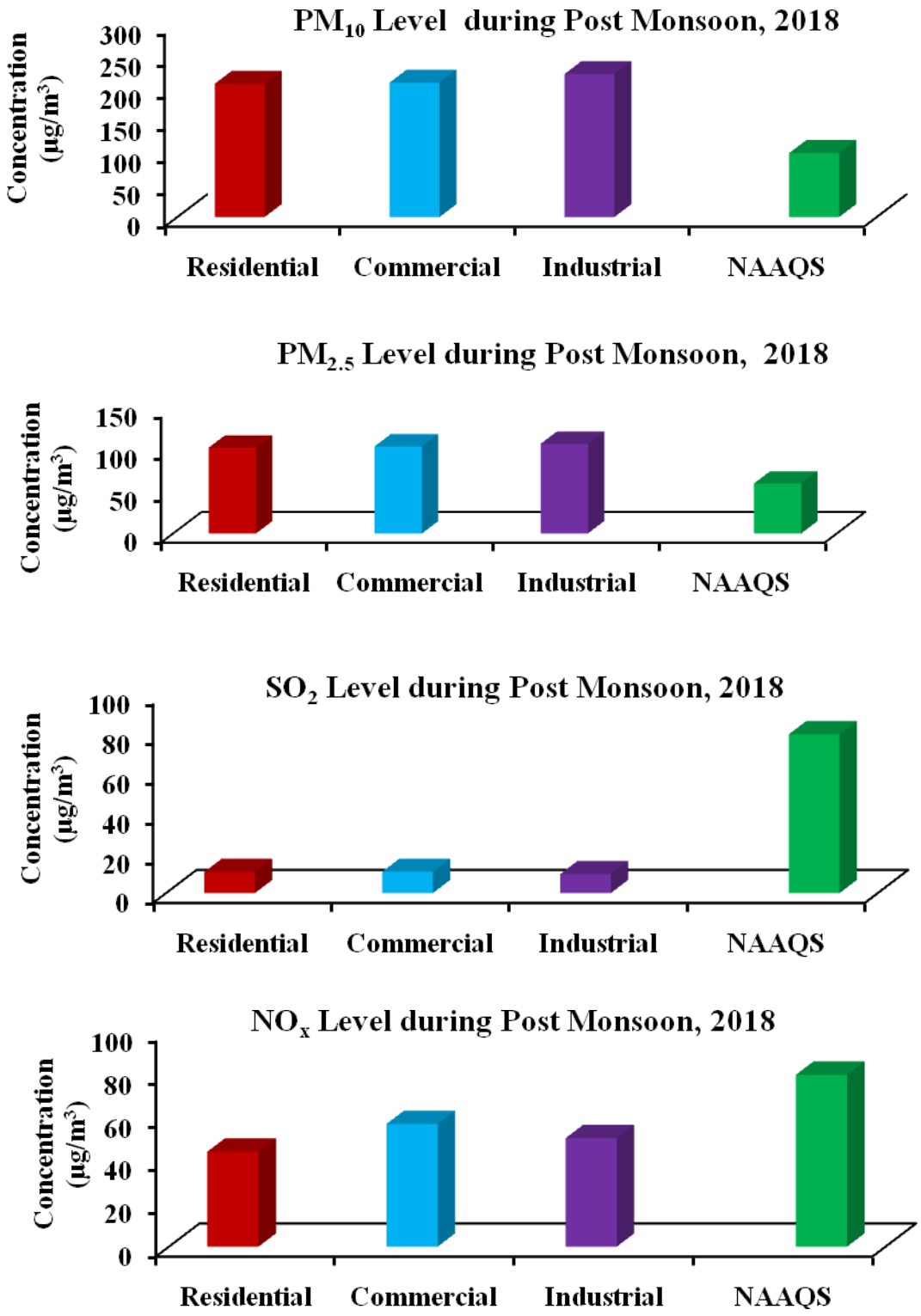

Figure 1: Concentration (µg/m^3) of PM_{10}, $PM_{2.5}$, SO_2 and NO_2 in different areas of Lucknow city during Post Monsoon season (2018) and their comparison with prescribed National Ambient Air Quality Standard (NAAQS)

1.3.5 Trace Metals in Ambient Air (RSPM or PM_{10})

Trace metals (Ni and Pb) were estimated in ambient air which are associated with PM_{10} at 9 monitoring locations. The results are present in Table 9. Twenty four hours mean concentration of metals in PM_{10} was found to be Ni = 15.96 (8.35 – 44.25) ng/m^3 and Pb = 103.14 (77.89 – 241.38) ng/m^3 .

Table 9
Metal Concentration in ng/m^3 associated with PM_{10}

S. No.	Location	Lead (Pb)	Nickel (Ni)
1	Aliganj	76.02	12.49
2	Vikas Nagar	77.94	10.18
3	Indira Nagar	88.03	13.96
4	Gomti Nagar	101.29	19.09
5	Charbagh	98.69	44.25
6	Alambagh	77.89	9.12
7	Aminabad	79.80	8.35
8	Chowk	87.24	9.41
9	Amausi	241.38	16.84
	Mean	**103.14**	**15.96**
	NAAQS	**1000.0***	**20****

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

1.3.6 Noise Level

The monitoring data recorded during the post monsoon period is presented in Table 10.

In residential areas, the day and night time noise levels were recorded between 66.3 to 71.9 and 55.1 to 60.3 dB(A) respectively. All the values were higher than the prescribed limit of 55 and 45 dB (A) for day and night time respectively.

In commercial and heavy traffic area, the day and night time noise level were recorded between 71.5 to 79.3 and 59.1 to 72.4 dB(A) respectively. Noise level at all the commercial sites during day and night time were found above the prescribed limit of 65 and 55 dB (A) respectively.

In industrial area Amausi, the day and night time noise levels were recorded 76.4 and 72.3 dB (A) respectively. Noise levels at the industrial location in the day and night time was found above the prescribed limit of 75.0 and 70.0 dB(A) respectively.

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

Sl. No.	Area	Location	Noise level dB(A)	
			Day	Night
1	**Residential**	Aliganj	71.9	59.5
		Vikas Nagar	66.3	57.0
		Indira Nagar	70.9	60.3
		Gomti Nagar	71.5	55.1
		Standard	**55.0**	**45.0**
2	**Commercial**	Charbagh	77.9	69.3
		Alambagh	70.2	59.1
		Aminabad	79.3	68.4
		Chowk	71.5	72.4
		Standard	**65.0**	**55.0**
3	**Industrial**	Amausi	76.4	72.3
		Standard	**75.0**	**70.0**

1.4 TRENDS OF AMBIENT AIR QUALITY IN LUCKNOW CITY

The observed PM_{10}, $PM_{2.5}$, SO_2 and NO_2 values from the last three years' data have been compared to find out the prevailing trend of air pollution in Lucknow city (Fig.2-5). Slight decrease or increase in the values may be attributed to some local environmental and climatic factors.

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

In all the locations in residential areas, higher values were found as compared to the previous year except Aliganj. Among the commercial areas, PM_{10} values were also found to be higher than the previous year except Aminabad and an industrial area showed higher value over the last year. All the values were found to be higher than NAAQS (Fig. 2).

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

In all the locations in residential areas, higher values were found compared to the previous year. Among the commercial areas, $PM_{2.5}$ values were found to be higher than the previous year except Charbagh and Aminabad where values dipped compared to the last year and an industrial area showed lower value over the last year. All the values are higher than NAAQS (Fig.3).

1.4.3 Sulphur dioxide (SO_2)

Lower concentration was found compared to the previous year at all the residential commercial and industrial areas. All the values were found to be lower than the NAAQS (Fig.4).

1.4.4 Nitrogen dioxide (NO_2)

The level of NO_2 during post monsoon since 2015 is presented in Fig. 4. All the residential areas except Vikas Nagar showed lower values than the previous year. In commercial areas the values for Aminabad and Charbagh dipped whereas those for Alambagh and Chowk rose. The industrial area, Amausi showed higher value compared to previous year. All the mean values of the present study were found to be lower than the NAAQS (Fig.5).

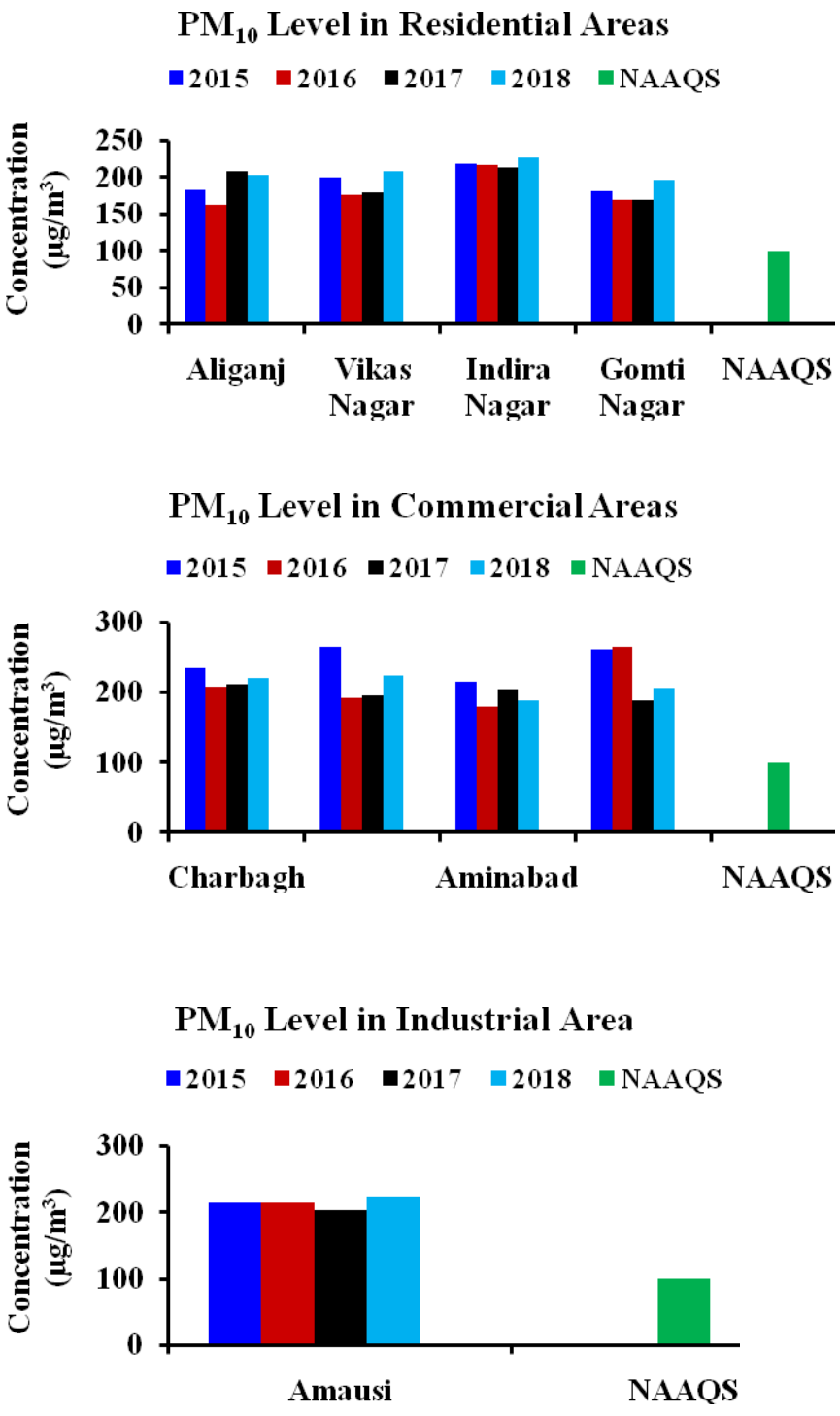


Figure 2: Concentration (µg/m^3) of PM_{10} **(**RSPM**)** in Residential, Commercial and Industrial areas of Lucknow city during 2015 to 2018 and comparison with prescribed National Ambient Air Quality Standard (NAAQS)

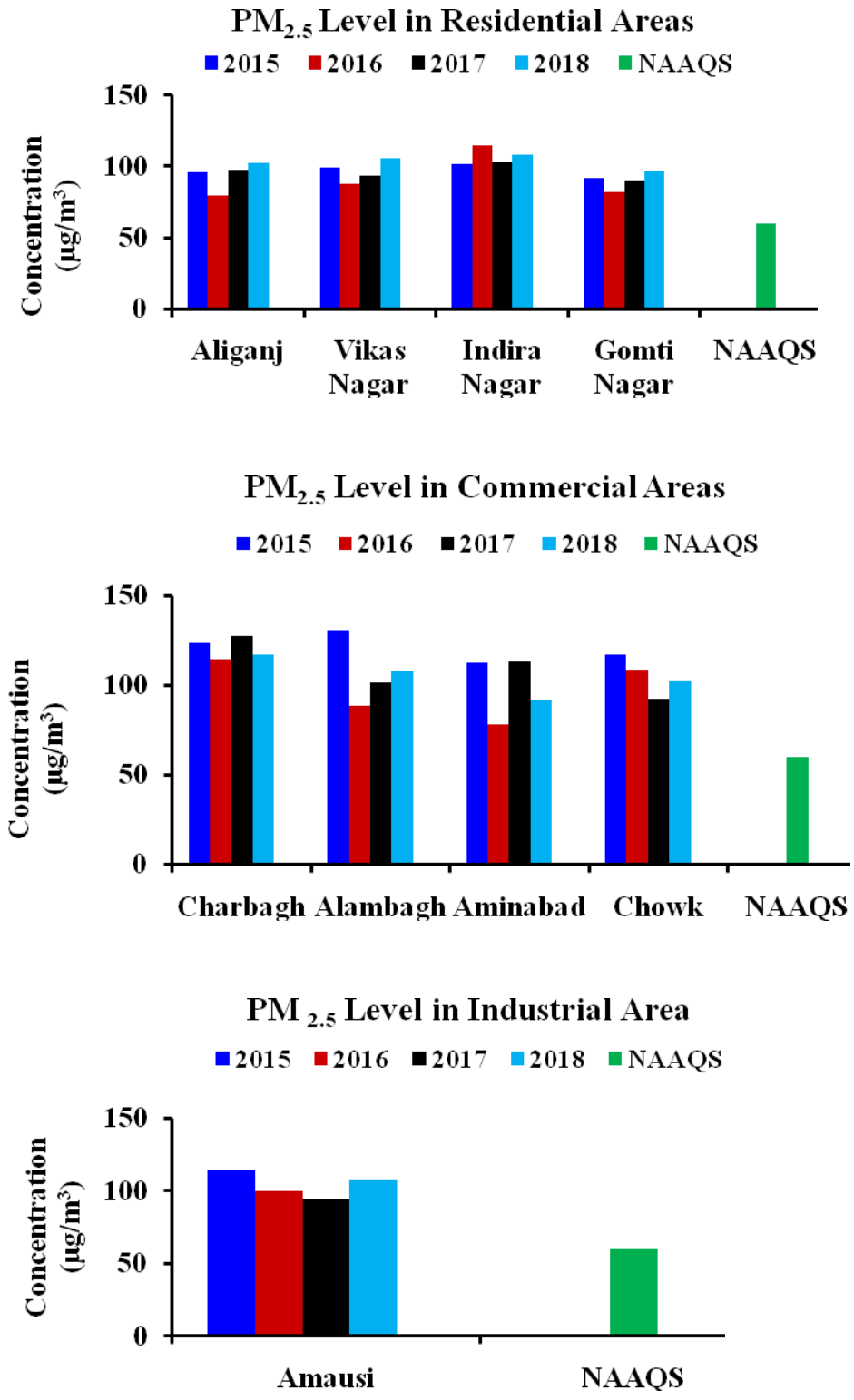
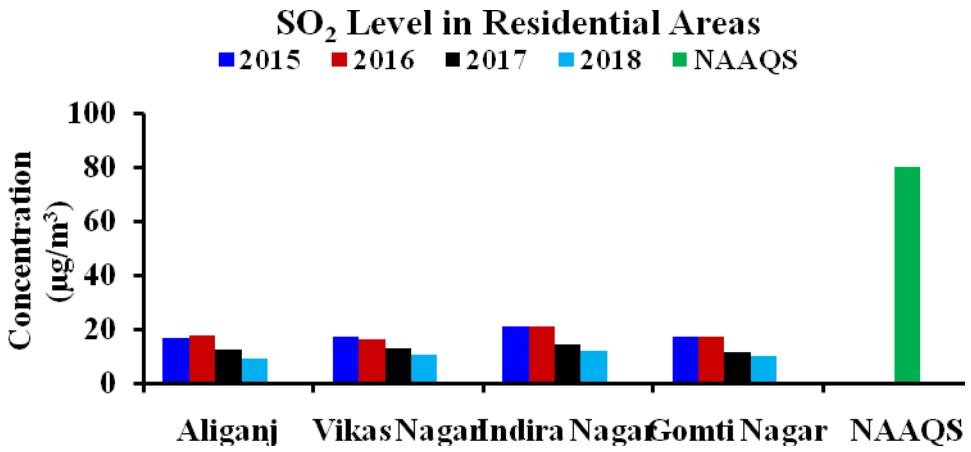
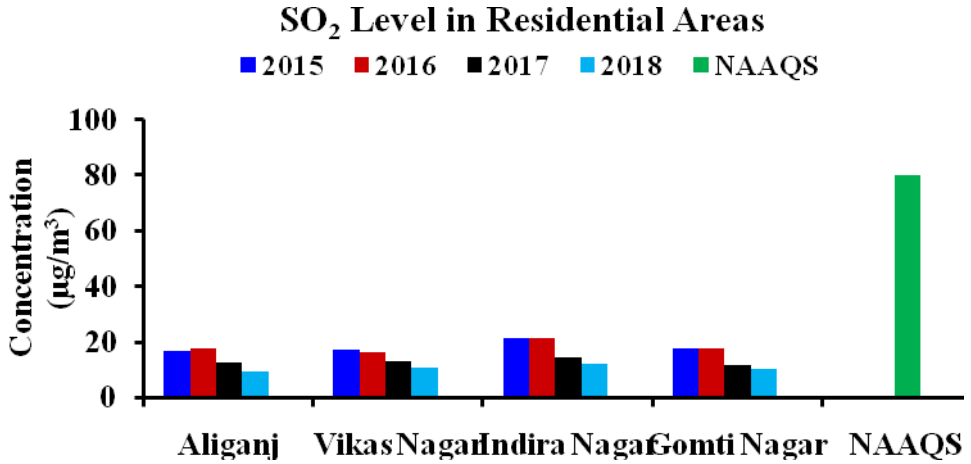


Figure 3: Concentration (µg/m^3) of $PM_{2.5}$ in Residential, Commercial and Industrial areas of Lucknow city during 2015 to 2018 and comparison with prescribed National Ambient Air Quality Standard (NAAQS)





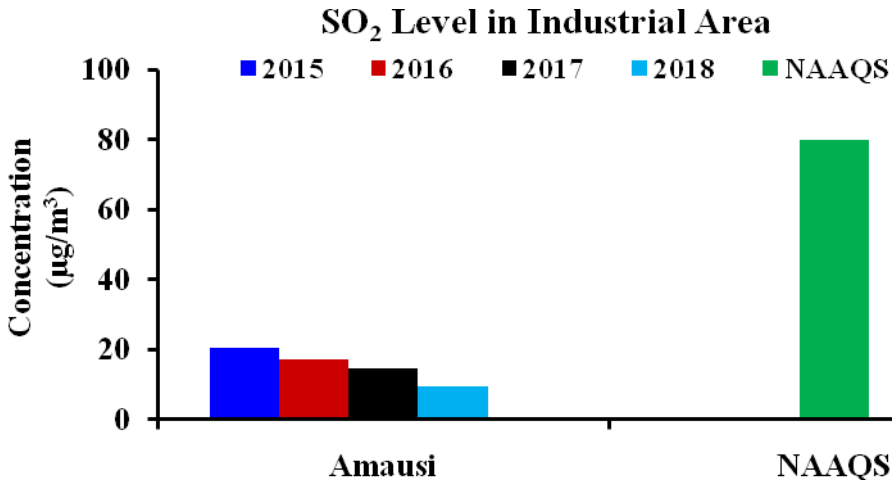


Figure 4: Concentration (µg/m^3) of SO_2 in Residential, Commercial and Industrial areas of Lucknow city during 2015 to 2018 and comparison with prescribed National Ambient Air Quality Standard (NAAQS)

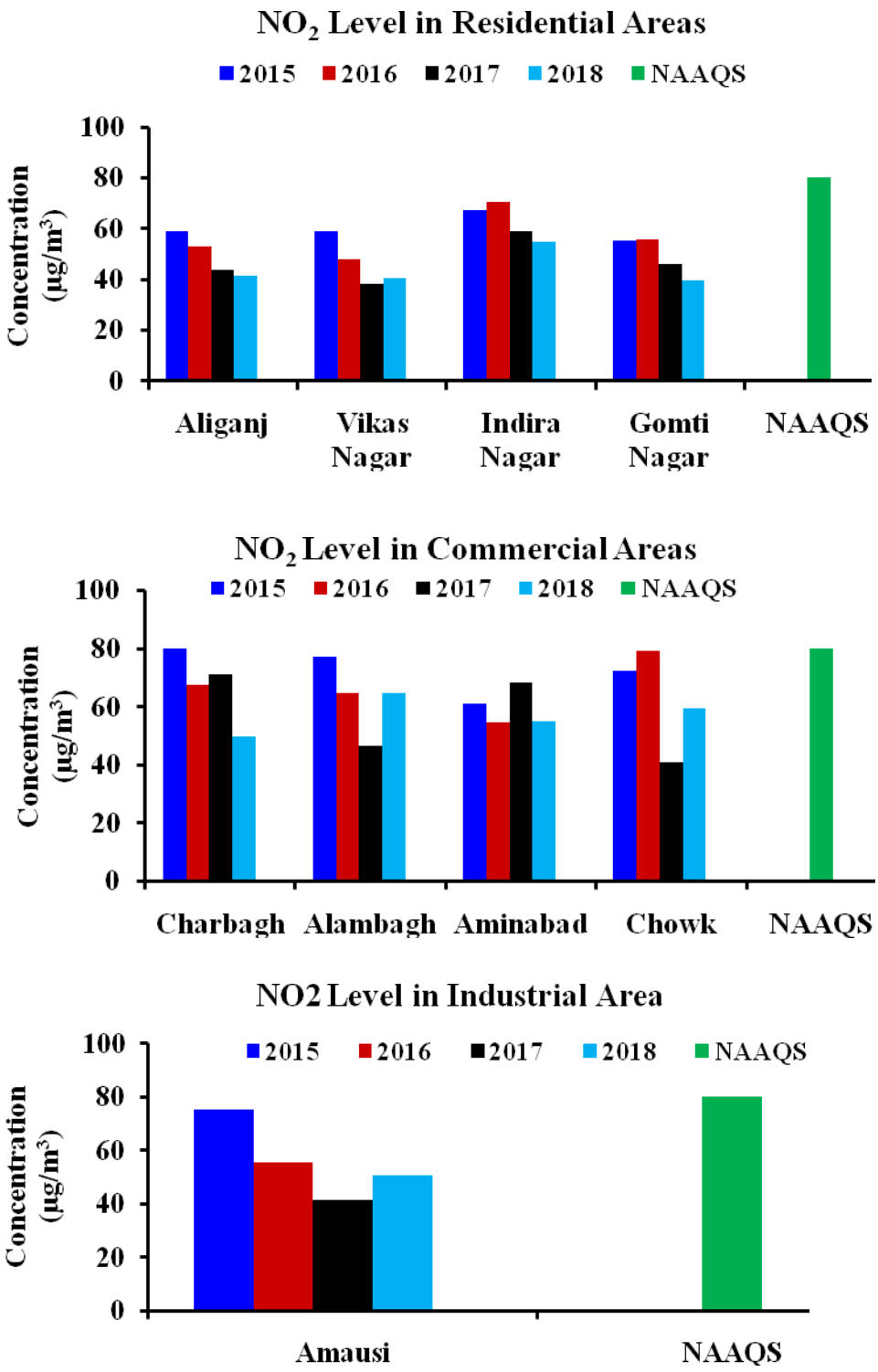


Figure 5: Concentration (µg/m^3) of NO_2 in Residential, Commercial and Industrial areas of Lucknow city during 2015 to 2018 and comparison with prescribed National Ambient Air Quality Standard (NAAQS)

1.4.4 Noise Level

Current year's noise data has been compared with the corresponding data of the previous three years and is presented in Fig.6 and Fig.7. Comparative noise level in residential, commercial and industrial areas are described below:

1.4.4.1 Day time Noise Level

In residential areas two locations showed slightly increasing trend over the previous year whereas the other two showed a decreasing trend. In commercial cum traffic areas, noise level was slightly on the lower side at all the locations compared to the previous year except Aminabad and Charbagh. In industrial area, Amausi the noise level was higher than the previous year. All noise levels surpassed the standards prescribed depending on the location. The comparative data are presented in (Fig.6).

1.4.4.2 Night time Noise Level

Residential, commercial as well as industrial areas showed higher trend for night time noise level apart from Aminabad and Chowk which showed slightly increasing trend than the last year level. All noise levels surpassed the standards prescribed depending on the location. The comparative data is presented in (Fig.7).

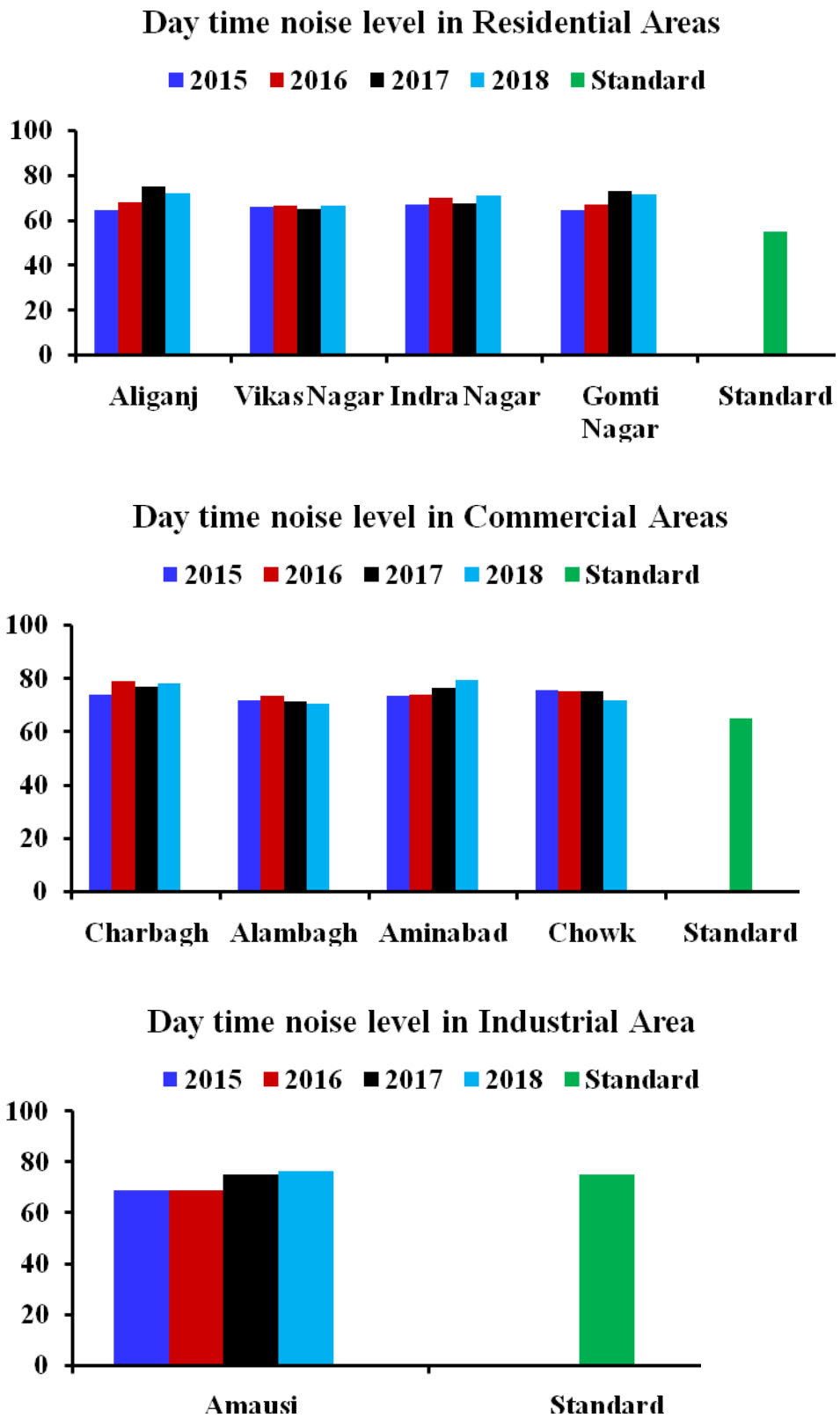


Figure 6: Comparison of day time Noise Level dB (A) in different areas of Lucknow city (2015-2018)

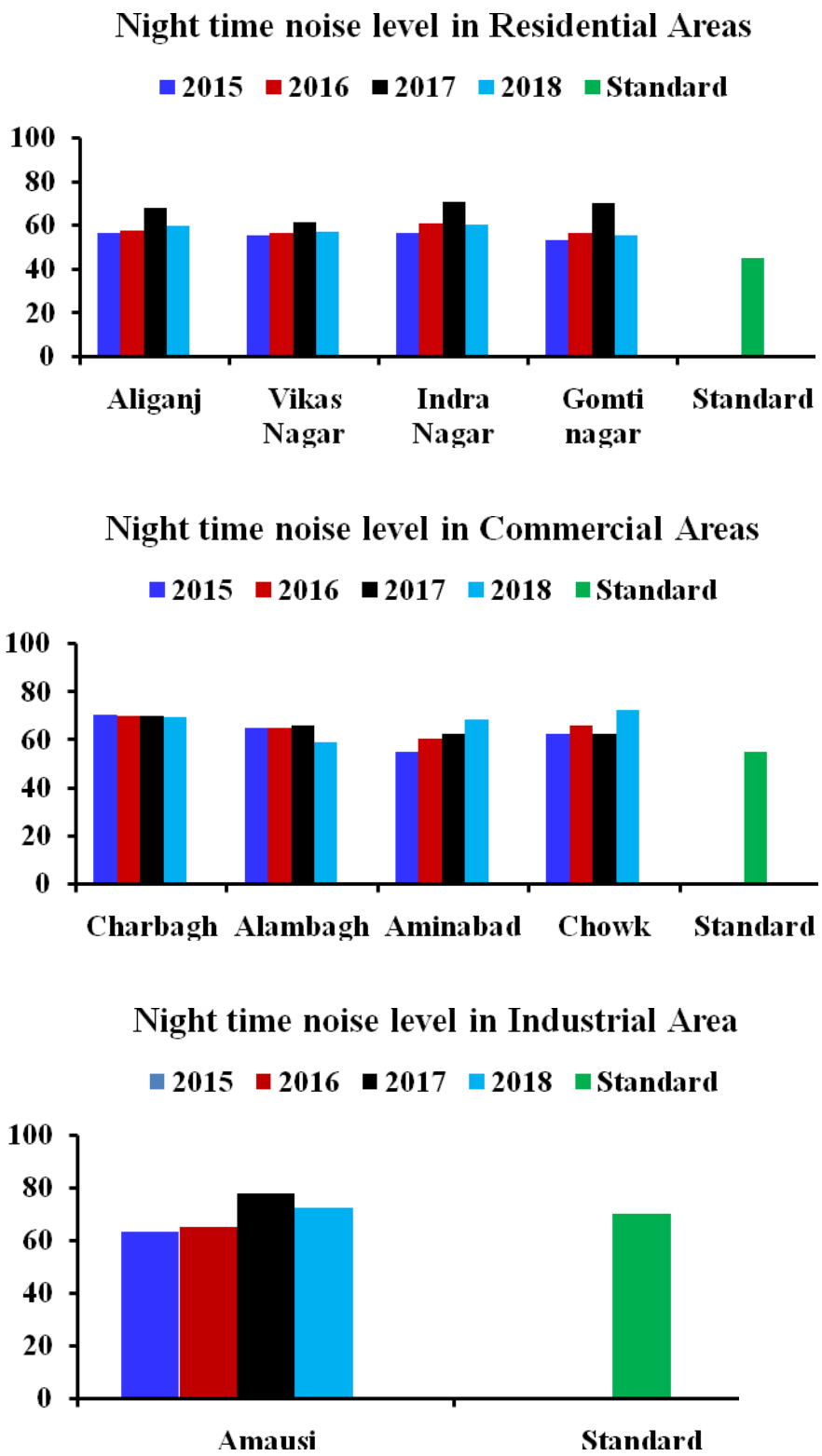


Figure 7: Comparison of night time Noise Level dB (A) in different areas of Lucknow city (2015-2018)

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 including (i) premature death (ii) aggravated asthma (iii) acute respiratory symptoms and (iv) 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 cardio vascular 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 (NOx) 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 facts that air born particles (PM_{10} and $PM_{2.5}$) at elevated level increase the mortality and morbidity in the exposed people. The exact mechanism of PMs toxicity is yet to be known. The degree of effectiveness depends on the physicochemical prop-

erties 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. The studied trace elements, Pb and Ni have been observed within the NAAQS 2009 limit in the present survey.

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 pollutant effects are given below:

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

Particulate Matter has a diameter ≤ 10 μm and diameter ≤ 2.5 μm when inhaled would penetrate beyond the larynx.

- Small particles penetrate deeply 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 lung 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)

Elevated value of SO_2 may cause- irritation of the eyes, nose and throat, choking and coughing.

- Reflex cough, irritation, and a feeling of chest tightness, which may lead to narrowing of the airways is particularly likely to occur in people suffering from asthma and chronic lung disease, whose airways are often inflamed and easily irritated.

- Oral inhalation of larger volumes may reach the segmental bronchi and damge the organ and exposure of the eyes (eg. in an industrial accident) can cause severe burns and result 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_x)

NO_x causes a wide variety of health and environmental impacts because of various compounds and derivatives in the family of NO_x 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.

In the present study, the concentration of SO_2 and NO_2 were found to be below permissible limit (80 µg/m3) of NAAQS (MoEF 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.

1.5.4 Health Effects of Trace elements

Lead (Pb)

- Lead is a neurotoxin. Impairment of neural development 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, anaemia in children
- Cognitive and neuro- behavioural deficits in children at low levels of exposure are a great concern.

Nickel (Ni)

- The harmful human health effect of nickel is 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

Elevated Noise levels of ambient air may 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.

1.6 CONCLUSIONS

Air pollutants such as PM_{10}, $PM_{2.5}$, SO_2 and NO_2, particulate trace metals and day v/s night noise level were monitored in order to assess the ambient air quality at 9 locations and sub fraction of fine particles at two locations, during post monsoon (Last week of September to October), 2018 and the data revealed the following salient points:

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

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

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

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

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

- Pre and post monsoon survey results indicate that throughout the year except monsoon season (winter season not covered, which is the worst period with respect to air pollution) particulate matter (PM_{10} and $PM_{2.5}$) levels remain higher than the permissible limit. Particulate matter is a carrier of other pollutants namely trace elements, Poly aromatic hydrocarbons (PAHs) etc. and among them some are carcinogenic. At present, more than 30 lakh people residing in urban area of Lucknow city are under continuous exposure to air pollutants and under the threat of health risks especially children, aged and the diseased.

- Rapid growth of number of vehicles, their technological development and release of invisible tailpipe pollutants emission are serious debatable issues even for the policy makers. Use of different types of fuels namely petrol, diesel and CNG make the environment more complex with respect to air quality and their possible synergistic effects on the human health. Overall, continuous accumulation of different types of pollutants and their exposure to human beings needs emergency attention of the policy makers, researchers and regulatory agencies.

There are several studies published throughout the world which suggests that at elevated level all chemicals in the environment including metals are toxic to living being including humans. In general, study of environmental pollution and its effects can be summarized in the following ways–source of pollutants followed by its concentration and composition (chemical and physical characters) in the ambient air followed by receptor (exposed person and their age group and socio economical condition as well life style)- exposure time and dose (inhalation) and health effects.

The composition and concentration of air pollutants is important criteria which are variable with time and space. In ambient air there are several compounds and it is difficult to study for a single compound and its effects. There may be cumulative and chronic exposure for longer period with low concentrations of multiple compounds. Therefore, the adverse effects not only depend on certain pollutants and their levels. The multiple compounds in the air at below recommended level may synergistically effects on human health negatively. Meteorological factors like wind speed; wind direction, solar radiation, temperature, relative humidity, etc play an important role for the speciation the ambient chemicals and formation of secondary compound and the scientific study also need to focus in this line.

Overall, air pollution and its control need active participation of general peoples, students, researchers (preferably local), social workers, regulatory bodies, administration, city planners etc. Our post monsoon monitoring survey might be of help to focus on the pollution level in Lucknow city and its probable consequences. Our database since 1997 will help the planners for sustainable development of city.

1.7 RECOMMENDATIONS FOR MITIGATION OF AIR POLLUTION

1. Major roads of the city should be widened as far as possible.
2. Suitable modification on crossings for smooth traffic flow.
3. Encroachment to be removed for smooth flow of traffic.
4. Foot path for pedestrians should be restored.
5. Provision of parking facilities by private operators on vacant private land.
6. Increase in the parking charges on hourly basis to discourage the use of personal vehicles in congested areas.
7. Subsidized public mass transport (Metro, Monorail etc.) must be strengthened to minimize use of personal vehicles.
8. Improvement in traffic management.
9. Public awareness programme of air pollution and its health effects, reduction of automobile pollution by proper maintenance of vehicles, driving skills.
10. Systematically develop residential complex at the periphery of the city with all facilities to reduce crowd from central areas of the city.
11. Provision of bus stands on all the outgoing highways to reduce traffic load inside the city.
12. Removal of garbage dumps along the roads.
13. Ban on burning of dry leaves, tyres or any other type of solid waste and arrangement for its proper disposal.
14. Plantation of trees wherever possible in parks, open spaces and road side areas.
15. Installation of more CNG filling stations across the city.
16. Encouragement for battery operated or hybrid vehicles.
17. Promoting solar energy as an alternate to D.G. sets.
18. Pressure horns to be removed from all vehicles and avoid/ minimize use of horn.
19. Proper development of infrastructure for electric vehicle.
20. In-depth study is needed in coordination with different areas of scientific experts - city planner, municipality engineers- regulatory bodies-administrative bodies etc because reducing air pollutants and its effects is not a simple undertaking.
21. **Installment of heavy dust removal system 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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