Assessment of Ambient Air Quality of Lucknow City

Pre-Monsoon 2018

Findings of a Random Survey

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PERSONNEL

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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 31/03/2018**	:	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}, $PM_{2.5}$, Sub-fraction of Fine Particles, SO_2, NO_X, 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, 2018

1.0 SUMMARY

The study was carried out during the months of April-May, 2018 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 particles ($PM_{2.5}$), Sulphur Dioxide (SO_2), Oxides of Nitrogen (NO_x), trace metals-Lead (Pb) and Nickel (Ni) and noise level at 9 representative locations, categorized as residential (four), commercial (four) and industrial (one) areas in Lucknow city. The results revealed the 24 hours concentration of PM_{10} to be in the range of 95.3 to 296.8 µg/m^3 with an average of 198.8 µg/m^3. The 24 hours concentration of $PM_{2.5}$ was found to be in the range of 41.3 to 145.2 µg/m^3 with an average of 94.6 µg/m^3. The average values of PM_{10} and $PM_{2.5}$ irrespective of locations were found to be above the permissible limit (100 µg/m^3 for PM_{10} and 60 µg/m^3 for $PM_{2.5}$ prescribed by MoEF). Twenty four hours concentration of SO_2 and NOx were found to be in the range of 5.1 to 19.7 and 19.8 to 101.3 µg/m^3 with average concentrations of 9.3 and 44.4 µg/m^3 respectively and all the mean values were below the permissible limits (80 µg/m^3). The mean level of trace metals were Pb = 49.23 and Ni = 9.62 ng/m^3. Noise levels during day and night time were found to be in the range of 67.0 to 83.4 dB (A) and 54.0 to 69.5 dB (A) respectively which was above the respective permissible limits.

1.1 INTRODUCTION

Good air quality is essential for good health for living beings including humans. The increase in human population, urbanisation and economic up-liftment led to an increase in the consumption of resources. The consumption oriented society as well as economy has resulted in a number of by-product including air pollutants which affect the air quality and ultimately deteriorate the health condition of living beings and resources.

In urban area rapid increase of vehicular population as well as road traffic is one of the major source of air pollutants and cause of health hazards. Vehicular pollution results from tailpipe emission mainly due to burning of petrol, diesel and CNG whereas some other non exhaust sources of vehicular pollution are tyre road friction, brake shoes and clutch wear. Other sources of urban air pollutants are burning of municipality solid waste, genset and re-suspension of soil, especially road side soil.

In modern urban life, increase in vehicle numbers and fuel consumption led to major sources of air pollutants like particulate matter (PM), nitrogen dioxide (NO_2), sulphur dioxide (SO_2), Ozone (O_3), carbon monoxide (CO), etc. There are several other pollutants like poly aromatic hydrocarbon (PAH's) and trace elements such as Fe, Ca, Pb, Cd, Cu, Ni, Co, As, etc associated with PMs and on the other hand PM can be considered as invisible carriers of these pollutants. These are the major pollutants are responsible for human health hazards, climatic changes leading to food security and visibility issues etc.

There are several research publications which suggest that the elevated level of these pollutants affect human being in different ways in human body systems such as respiratory, cardiovascular, immunological, haematological, neurological, reproductive/ developmental system and some of the health effects are asthma, irritation of the lungs, bronchitis, pneumonia, respiratory infections, premature death, etc.

Now-a-days, urban air quality is a serious issue because millions of people are exposed to high level of air pollutants mainly particulate matter and its associated organic and inorganic pollutants, which are responsible for severe health problem of all living beings including humans throughout the world especially in south Asian countries. The outcome

of ongoing scientific work has drawn serious attention of regulatory bodies, researchers, students, policy makers and even politicians along with general people. The ultimate human health effects due to air pollutants have changed the mindset of policy makers and regulatory bodies of respective countries towards revision the norms in respect of standards of each pollutant and attempts to gradually restrict their release from sources.

In urban areas, there are several factors which determine air quality as well as pollution levels like meteorological properties of the atmosphere, topographical influence, emission sources, physical and chemical nature of pollutants like in case of PM: density, shape and hygroscopic nature etc.

CSIR-Indian Institute of Toxicology Research (CSIR-IITR), Lucknow took up the issue seriously, way back in 1997 and has been striving hard since then for creation of mass awareness among public, scientific community, academicians and regulatory authorities. We have ensured skill development of sizable number of students, by providing training, in the areas of monitoring, testing and management of air pollutants. In this connection, CSIR-IITR has been assessing ambient air quality of urban area of Lucknow city during pre (April and May) and post (September and October) monsoon with respect to criteria pollutants namely Particulate Matter, SO_2 and NO_x since 1997.

Lucknow is a fast growing city. In 1951, area of Lucknow was 48 sq km which has now increased to 310 sq km in 2011. As per 2011 census, the city has a population of 28.15 lakh (Municipal Corporation + Cantonment).

In the proposed master plan 2031 (Lucknow Development Authority), the area of the city will increase to 654 sq km by inclusion of 197 villages, with a projected population of 65 lakh. This will lead to the change of land use plan of existing open/ agricultural area to residential, commercial or industrial. The net result would be more activities and more population. The, first phase of metro rail construction from Airport to Charbagh railway station is yet to be completed, and the 2nd phase (underground) from Charbagh to Parivartan Chowk and then onwards to Munshipulia via IT Chauraha is under progress. Traffic on these main routes of the city is badly affected. Particularly the fleet of special

purpose vehicle (Luxury low floor CNG city buses) operated by Lucknow City Transport Services Limited (LCTSL) have been forced to change their route due to metro construction resulted in the drastic downfall in passenger numbers. The passengers have begun to use small vehicle (autos etc.) on regular routes (narrowed due to metro construction) with more vehicles and heavy traffic jam leading to high emission during the construction phase along the metro rail route.

Vehicular traffic is the main source of particulate air pollution in Lucknow city. The number of different categories of vehicles registered with RTO (Regional Transport Office) Lucknow is 20,08,190 as on 31.03.2018 which is 1.51% higher (figures are under review) over the last year (Table 1). 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 31.03.2018 are given in Table 2. In Lucknow city there are 110 filling stations for petrol, diesel and CNG operated by different oil and gas companies (Table 3).

As per Oil Marketing Company (IOC, BPC and HPCL), the consumption/sale of petrol and diesel was 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 nine CNG filling stations and consumption of CNG in 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 is summarized in Table 5. The expansion of city is still continued, converting the land use from agricultural to residential/ commercial/ industrial. As a result, there has been an increase in air pollution levels of the city. Considering the above, assessment of ambient air quality of Lucknow city was carried out at 9 locations during pre monsoon (April-May), 2018 with respect to PM_{10}, $PM_{2.5}$, sub-fraction of fine particles, SO_2, NO_x, trace metals and noise level with the following aims and objectives:

- *To assess the ambient air quality with respect to PM_{10}, $PM_{2.5}$, SO_2, NO_x, and trace metals (Ni and Pb) 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
		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
8	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 –	1	180 minute

		Kapoorthala - Badshahnagar – Nishatganj – Hussainganj – Charbagh – Alambagh -Bhudeswar Chowraha - Dr. Sukuntala Mishra University.		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.N.	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, Green Gas Limited, Lucknow*

1.2 MONITORING LOCATIONS AND METHODOLOGY

Nine air quality monitoring locations representing different activities/areas i.e., four in residential, four in commercial cum traffic and one industrial area were selected for the study as summarized in Table 6. The parameters and methodology for the monitoring are mentioned 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

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

1.3 RESULTS

The detailed results of air quality monitoring are presented in Table 8 and Figure1.

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 190.8 to 213.6 µg/m^3 with an average of 201.8 µg/m^3. In commercial areas (Charbagh, Alambagh, Aminabad and Chowk) the average concentrations of PM_{10} were in the range of 186.5 to 216.2 µg/m^3 with an average of 196.3 µg/m^3 respectively. In industrial area (Amausi), the average concentration of PM_{10} was 196.9 µg/m^3.

The maximum 24 hours mean concentration of PM_{10} was observed in Indira Nagar (213.6 µg/m^3) in residential area and Charbagh (216.2 µg/m^3) in commercial areas. All the values of PM_{10} were above the prescribed National Ambient Air Quality Standard (NAAQS) of 100 µg/m^3 for industrial, residential, rural and other areas respectively.

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

In residential areas (Aliganj, Vikas Nagar, Indira Nagar and Gomti Nagar), the 24 hours average concentrations of $PM_{2.5}$ were in the range of 87.2 to 99.6 µg/m^3 with an average of 93.7 µg/m^3. In commercial areas (Charbagh, Alambagh, Aminabad and Chowk) the average concentrations of $PM_{2,5}$ were in the range of 90.6 to 105.4 µg/m^3 with an average of 96.9 µg/m^3 respectively. In industrial area (Amausi), the average concentration of $PM_{2.5}$ was 89.4 µg/m^3.

The maximum 24 hours mean concentration of $PM_{2.5}$ was observed in Indira Nagar (99.6 µg/m^3) residential area and Charbagh (105.4 µg/m^3) in commercial area. All the 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 areas.

1.3.3 Sub Fraction of Fine Particles (PM_1, $PM_{0.56}$, $PM_{0.32}$, $PM_{0.18}$, $PM_{0.1}$)

The monitoring of sub fractions of fine particles was conducted during the month of May, 2018 at two locations i.e. city commercial area (CSIR-IITR, Main Campus) and in rural area (CSIR-IITR, Gheru Campus) are reported in Table 9. The 24 hours mean mass concentrations of PM_1, $PM_{0.56}$, $PM_{0.32}$, $PM_{0.18}$ and $PM_{0.1}$ were found to be 24.43, 16.36, 18.04, 18.09 and 16.07 µg/m^3 respectively and total particulate level was 92.99 µg/m^3 in city commercial area. Similarly mass concentration in all the same fractions values for village/rural area were 14.62, 14.69, 10.12, 6.33 and 8.05 µg/m^3 respectively with total value of 53.82 µg/m^3. Average concentration of particulate matter in sub-fractions was higher in commercial area of Lucknow city as compared to rural area (Figure 2). For these particles, no International and National guideline is available at this point of time.

1.3.4 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 8.0 to 9.6 µg/m^3 with an average of 8.7µg/m^3. In commercial areas (Charbagh, Alambagh, Aminabad and Chowk) the average concentrations of SO_2 were in the range of 10.1 to 10.7 µg/m^3 with an average of 10.3 µg/m^3. In industrial area (Amausi), the mean level of SO_2 was 7.9 µg/m^3.

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

1.3.5 Oxides of Nitrogen (NO_x)

In residential areas (Aliganj, Vikas Nagar, Indira Nagar and Gomti Nagar) the 24 hours average concentrations of NO_X were found in the range of 32.1 to 44.6 µg/m^3 with an average of 37.8 µg/m^3. In commercial areas (Charbagh, Alambagh, Aminabad and Chowk) the average concentrations of NO_X were found in the range of 44.3 to 56.2 µg/m^3 with an average of 51.6 µg/m^3. In industrial areas (Amausi), the average concentration was 41.7 µg/m^3.

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

Table 8
Concentration (µg/m^3) of PM_{10}, $PM_{2.5}$, SO_2 and NO_x during pre monsoon 2018

Location	PM_{10} (RSPM)			$PM_{2.5}$			SO_2			NOx		
Residential												
	Min	**Max**	**Avg**	**Min**	**Max**	**Avg**	**Min**	**Max**	**Avg**	**Min**	**Max**	**Avg**
Aliganj	121.3	264.4	198.9	66.9	116.5	96.0	7.4	9.7	8.4	30.7	41.2	33.8
Vikas Nagar	95.3	271.3	204.1	41.3	137.7	91.9	6.0	11.7	8.7	27.7	53.7	40.6
Indira Nagar	168.0	296.8	213.6	80.8	131.4	99.6	6.6	14.4	9.6	29.8	56.3	44.6
Gomti Nagar	136.4	239.0	190.8	62.6	111.0	87.2	6.7	9.9	8.0	19.8	46.4	32.1
Commercial												
Charbagh	128.3	294.6	216.2	63.0	145.2	105.4	6.6	13.2	10.1	41.8	66.4	51.6
Alambagh	158.4	219.1	186.5	76.3	124.4	90.6	5.1	19.7	10.2	29.8	81.6	56.2
Aminabad	118.5	245.8	177.3	63.5	132.1	99.1	6.3	16.0	10.7	27.3	101.3	44.3
Chowk	104.4	248.3	205.2	62.2	117.0	92.6	7.1	13.4	10.3	43.6	68.7	54.3
Industrial												
Amausi	153.8	232.2	196.9	63.8	112.4	89.4	6.5	9.4	7.9	31.6	53.2	41.7
NAAQS	100			60			80			80		
WHO Guidelines	50			25			20*			40*		

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

Table 9
Mass concentration of Sub Fraction of Fine Particles (24 hours mean) during Pre Monsoon 2018

Sub-Fraction of Fine Particulates	City commercial area (CSIR-IITR M.G. Road Campus)			Rural area (CSIR-IITR Gheru Campus)		
	Min.	Max.	Avg.	Min.	Max.	Avg.
$PM_{1.0}$ (≤1μm)	23.61	25.56	24.43	11.94	17.59	14.62
$PM_{0.56}$ (≤0.56μm)	14.81	17.41	16.36	12.09	18.06	14.69
$PM_{0.32}$ (≤0.32μm)	10.65	24.26	18.04	8.06	11.50	10.12
$PM_{0.18}$ (≤0.18μm)	18.06	18.33	18.09	6.02	6.56	6.33
$PM_{0.1}$ (≤100nm)	11.57	19.54	16.07	7.26	8.80	8.05
Total (fine)	**78.70**	**105.10**	**92.99**	**45.37**	**62.51**	**53.82**

No. of samples = 3; Instrument used: MOUDI Cascade Impactor, USA

Micro Orifice Uniform Deposit (MOUDI) Cascade Impactor

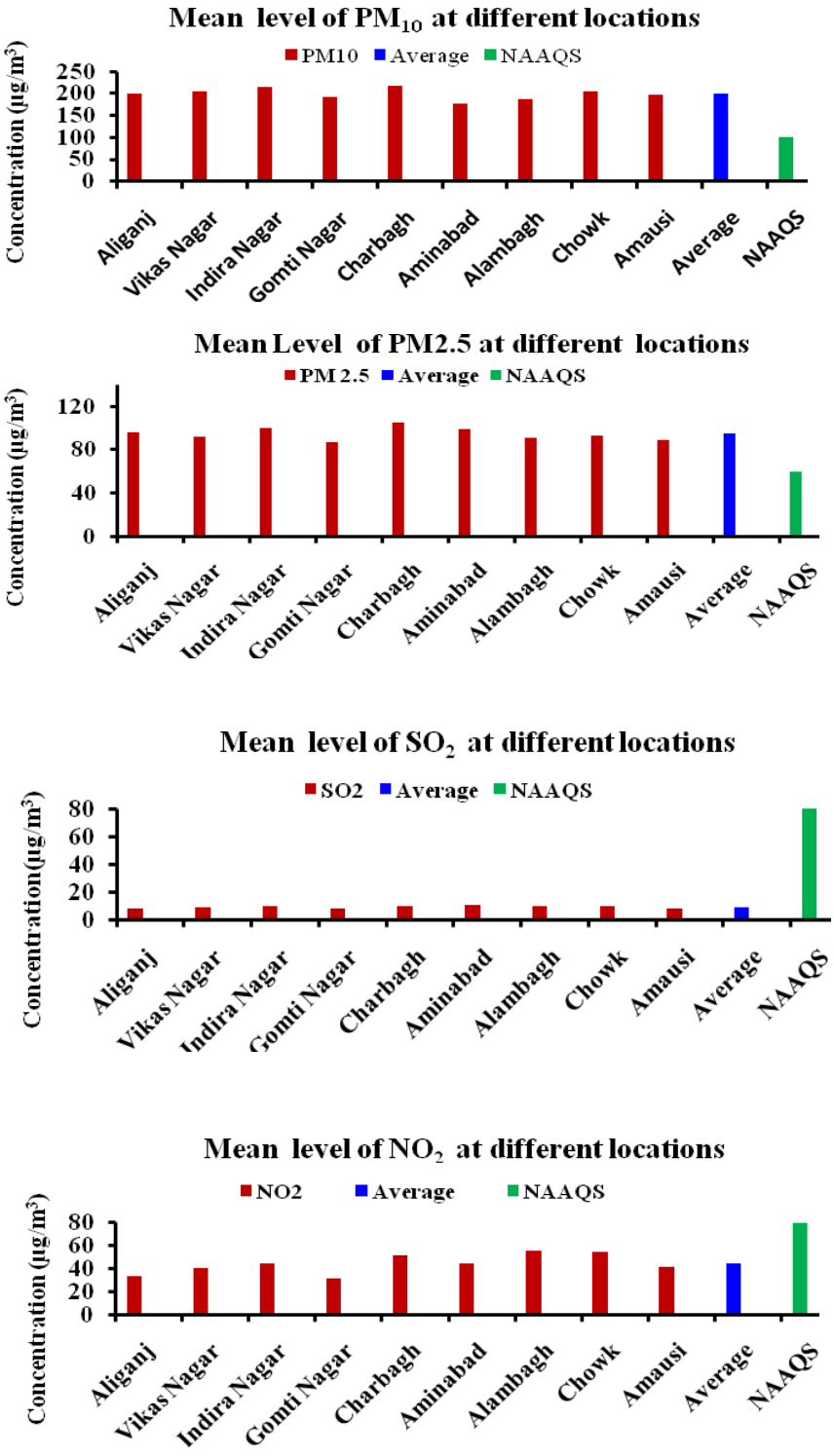

Figure 1: Concentration (µg/m^3) of PM_{10}, $PM_{2.5}$, SO_2 and NO_x in different areas of Lucknow city during pre monsoon season (2018) compared with prescribed National Ambient Air Quality Standard (NAAQS)

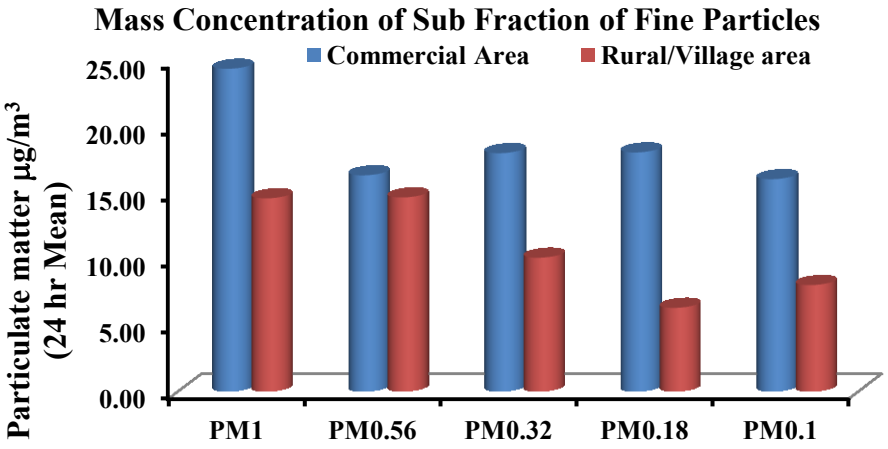

Figure 2: Pre-Monsoon levels of particulate matter in fine particle sub-fraction

1.3.6 Trace Metals in Ambient Air (RSPM)

The trace metals (Pb and Ni) were estimated in ambient air associated with PM_{10} at 9 monitoring locations. The results are present in Table 10. The 24 hr mean concentration of metals were found to be Pb = 49.23 (31.35 -113.90) and Ni = 9.62 (5.98 – 14.18) ng/m^3.

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

S.No.	Location	Pb	Ni
1	Aliganj	31.35	5.98
2	Vikas Nagar	45.38	8.05
3	Indira Nagar	44.52	9.25
4	Gomti Nagar	43.98	11.93
Mean		**41.31**	**8.80**
5	Charbagh	36.36	14.18
6	Alambagh	39.54	10.40
7	Aminabad	40.19	6.61
8	Chowk	113.90	10.62
Mean		**57.50**	**10.45**
9	Amausi	47.84	9.52
NAAQS		**1000**	**20***

N= 1, *=Annual Average

1.3.7 Noise Level

The noise monitoring data recorded during the pre monsoon period (May, 2018) is presented in Table 11.

In residential areas, the day and night time noise levels were recorded between 67.0 to 79.8 and 54.0 to 62.7 dB(A) respectively. All the values were higher than the prescribed limits of 55 and 45 dB (A) for day and night time respectively.

In commercial and traffic area, the day and night time noise levels were recorded between 76.2 to 83.4 and 56.2 to 68.7 dB(A) respectively. Noise level at all the commercial sites during day and night time were found above the prescribed limits of 65 and 55 dB (A) respectively. In industrial area Amausi, the day and night time noise levels were recorded 80.1 and 69.5 dB (A) respectively. Noise levels at industrial area during day and night time were recorded higher than the prescribed limits of 75.0 and 70.0 dB(A) respectively.

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

S. No.	Area	Location	Noise level dB(A)	
			Day	Night
1	**Residential**	Aliganj	67.0	62.7
		Vikas Nagar	70.2	54.0
		Indira Nagar	79.8	60.1
		Gomti Nagar	76.7	58.4
		Standard	55.0	45.0
2	**Commercial**	Charbagh	83.4	68.7
		Alambagh	80.4	56.2
		Aminabad	76.2	63.8
		Chowk	81.3	71.1
		Standard	65.0	55.0
3	**Industrial**	Amausi	80.1	69.5
		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_x data for 3 years have been compared to find out the prevailing trend of air pollution in Lucknow city (Figures 3-6). 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})

In the residential areas, comparatively lower values were found at all the residential areas except for Vikas Nagar, whereas lower values were also observed in all commercial areas and one industrial area when compared to the data of the previous year. All the mean values are higher than the NAAQS (Figure 3).

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

The level of $PM_{2.5}$ has been compared with last three year data and all the values of residential, commercial and industrial areas were found to be lower than the previous year. All the mean values of the present study were found to be higher than the NAAQS (Figure 4).

1.4.3 Sulphur dioxide (SO_2)

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

1.4.4 Oxides of Nitrogen (NO_x)

The level of NOx during pre monsoon since 2015 is presented in Figure 6 for all the locations. Among the residential and commercial areas all the locations showed decreasing trend, and only one commercial area Alambagh showed higher value when compared with the previous year data. All the mean values of the present study were

found to be lower than the NAAQS (Figure 6).

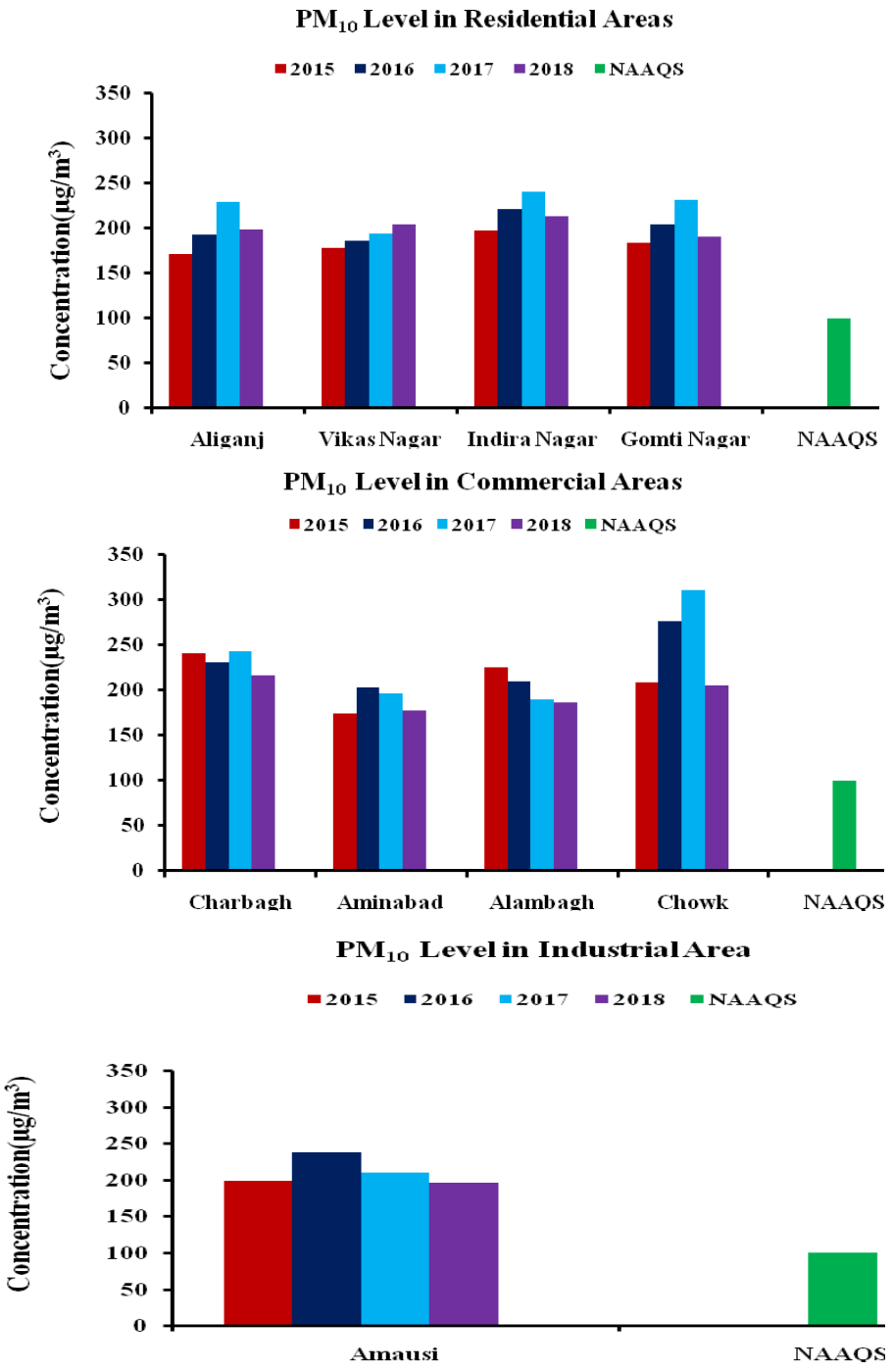

Figure 3: Concentration (µg/m^3) of PM_{10} **(**RSPM**)** in Residential, Commercial and Industrial areas of Lucknow city during 2015 to 2018 and compared with prescribed National Ambient Air Quality Standard (NAAQS)

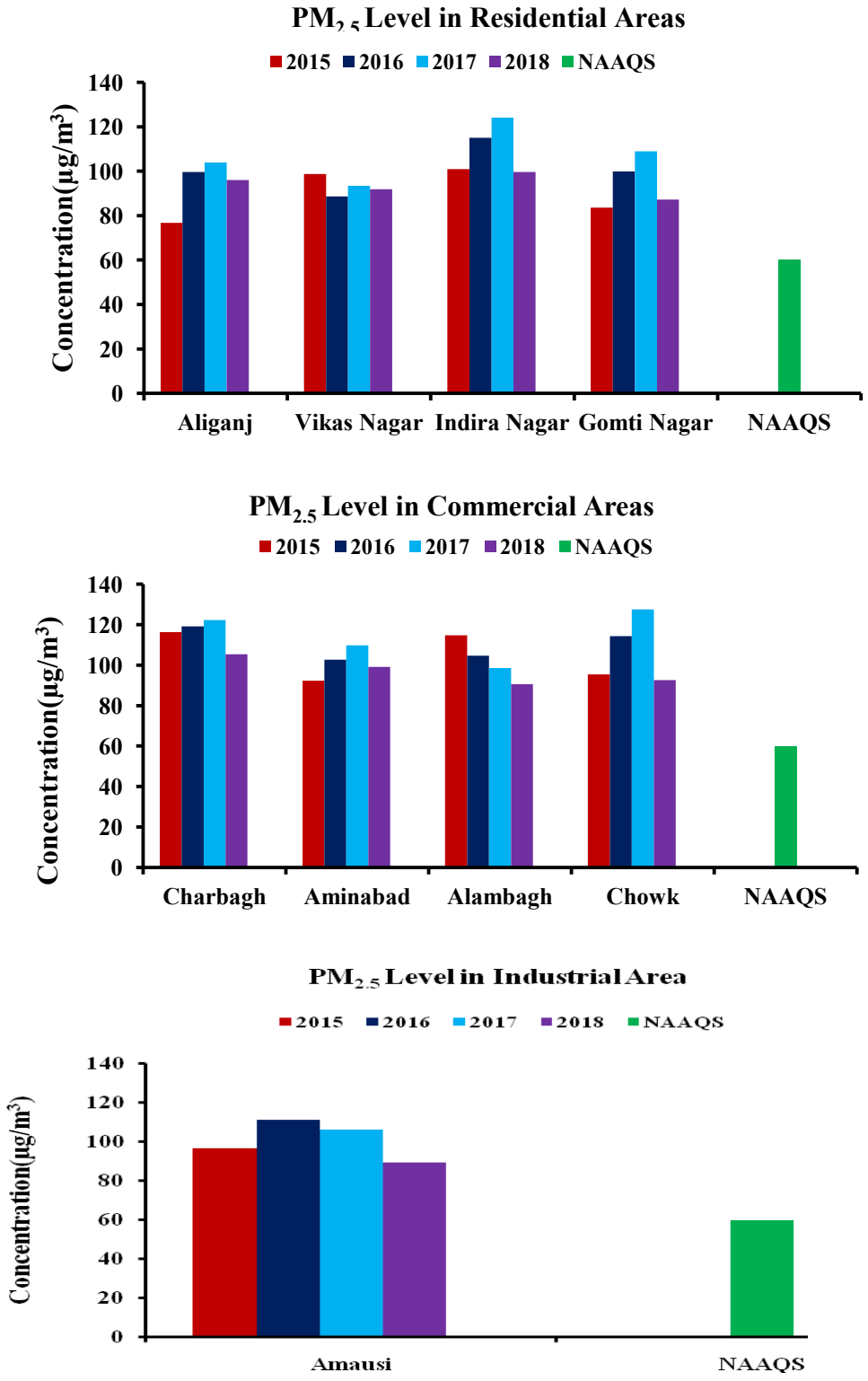

Figure 4: Concentration (µg/m^3) of $PM_{2.5}$ in Residential, Commercial and Industrial areas of Lucknow city during 2015 to 2018 and compared with prescribed National Ambient Air Quality Standard (NAAQS)

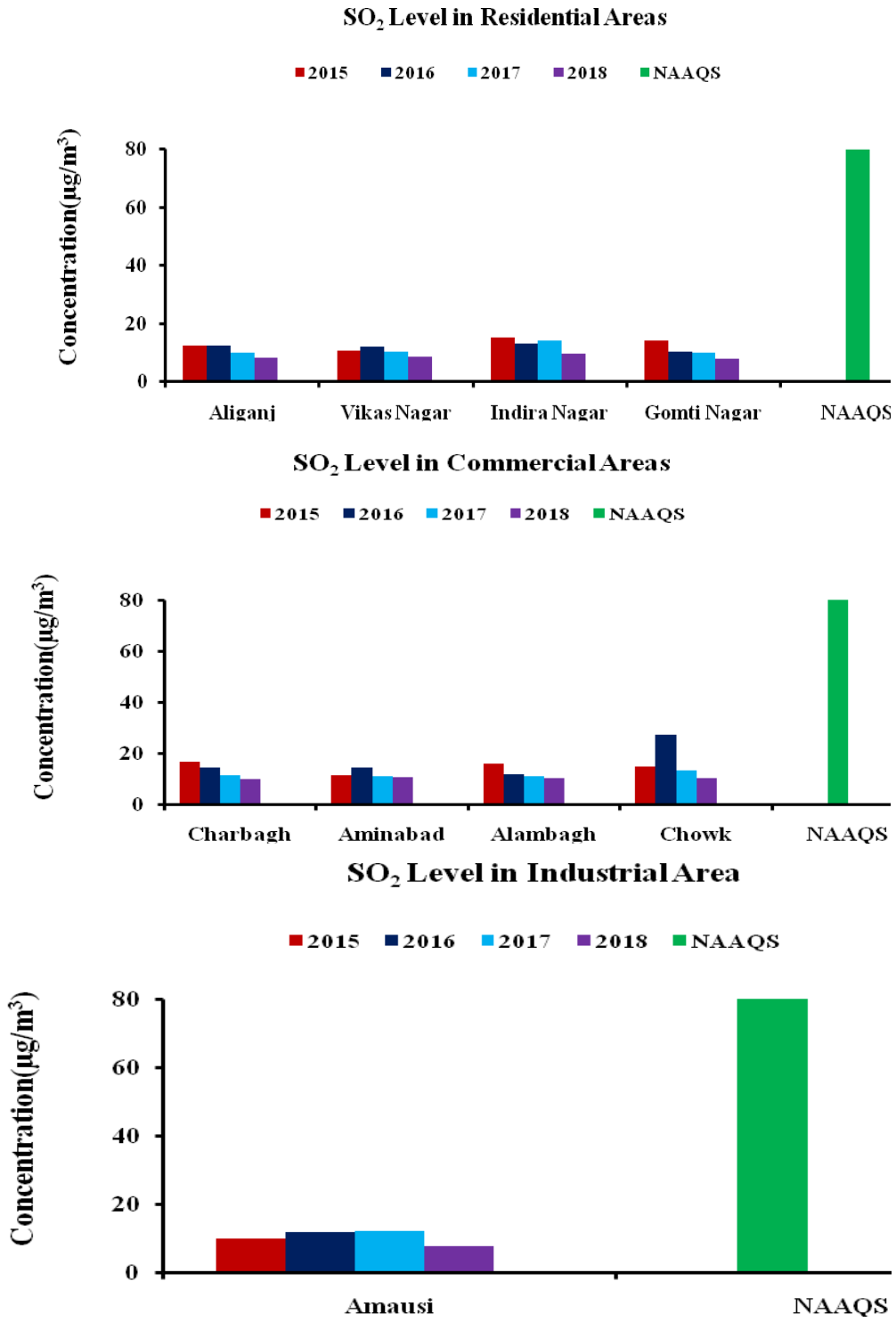

Figure 5: Concentration (µg/m^3) of SO_2 in Residential, Commercial and Industrial areas of Lucknow city during 2015 to 2018 and compared with prescribed National Ambient Air Quality Standard (NAAQS)

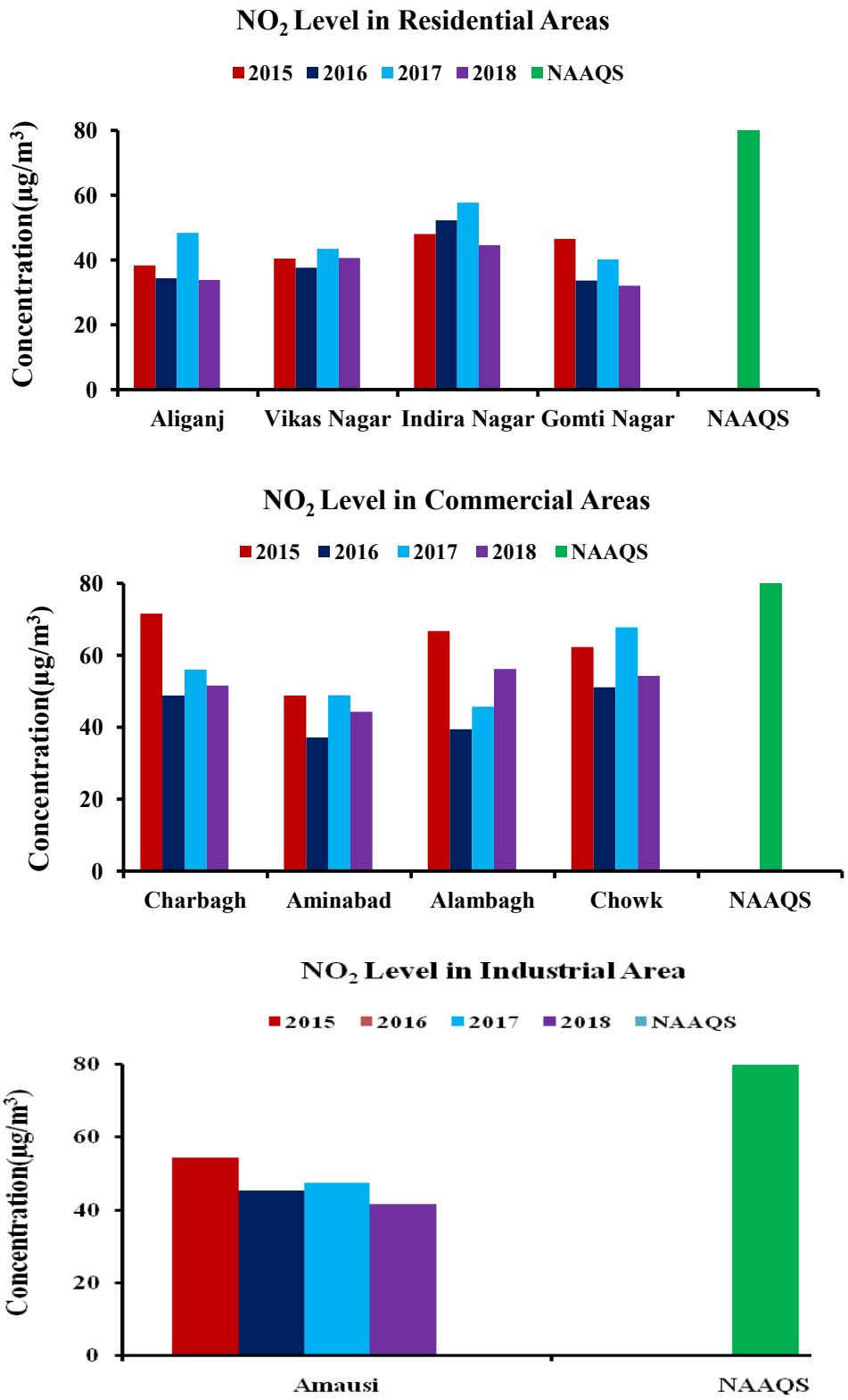

Figure 6: Concentration (µg/m^3) of NO_x in Residential, Commercial and Industrial areas of Lucknow city during 2015 to 2018 and compared with prescribed National Ambient Air Quality Standard (NAAQS)

1.4.5 Noise Level

Current year's noise data was compared with the corresponding data of the previous three years (2015 to 2018) and presented in Figure 7 and 8. The comparative noise levels in residential, commercial and industrial areas are described below:

1.4.5.1 Day time Noise Level

In residential areas, all the locations showed slightly increasing trend over that of the previous year. In commercial cum traffic areas, also noise level was found to be on the higher side at all the locations compared to that of previous year. In industrial area (Amausi) too noise level was slightly higher than that of the previous year. The comparative data are presented in Figure 7.

1.4.5.2 Night time Noise Level

Residential areas showed slightly higher level than that of the last year except Vikas Nagar and Indra Nagar. In commercial areas, little variation in higher side was recorded at all locations except Alambagh and the only industrial area showed slightly higher value than that of the previous year. The comparative data are presented in Figure 8.

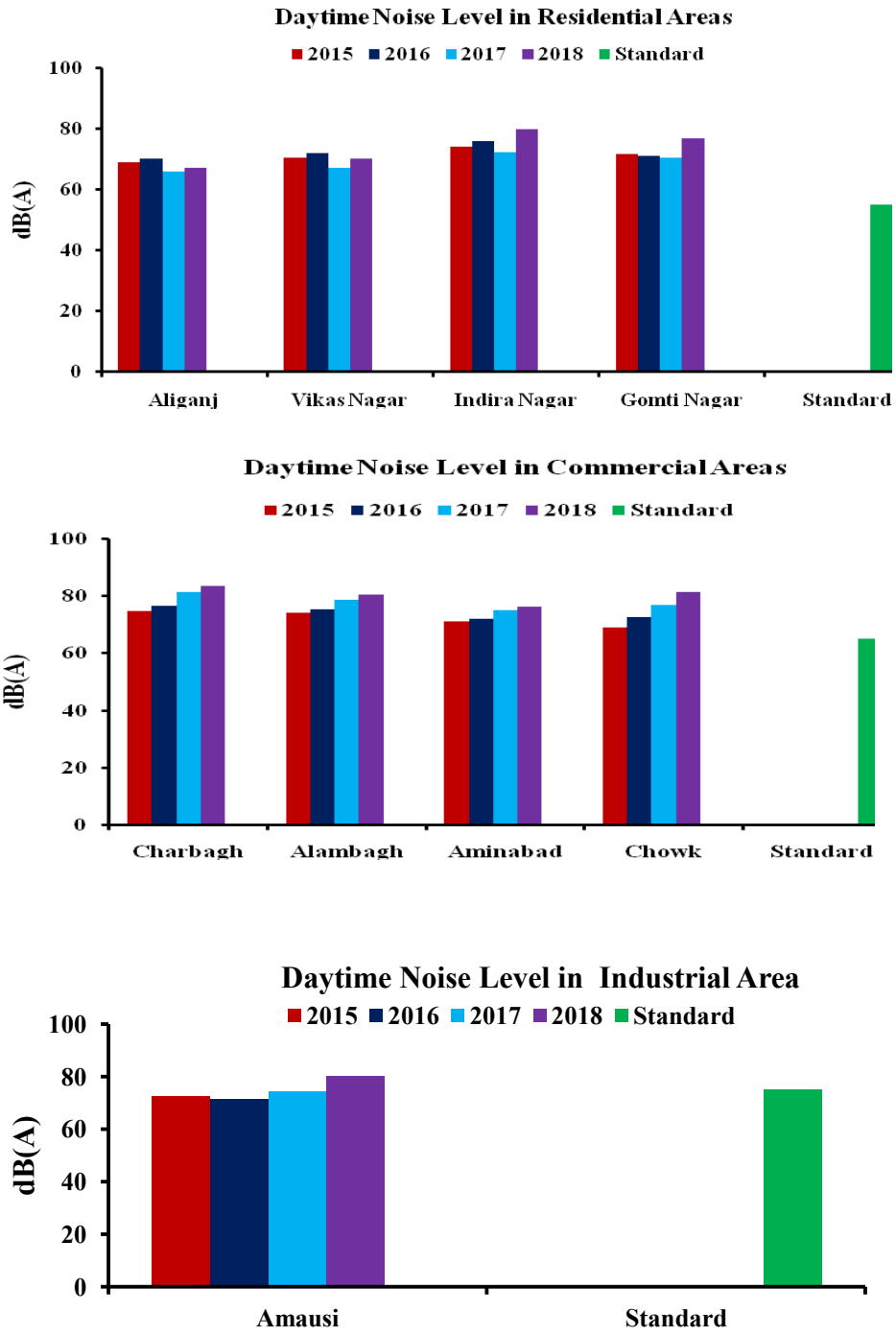

Figure 7: Comparison of day time Noise Level dB(A) in different areas of Lucknow city (2015-2018)

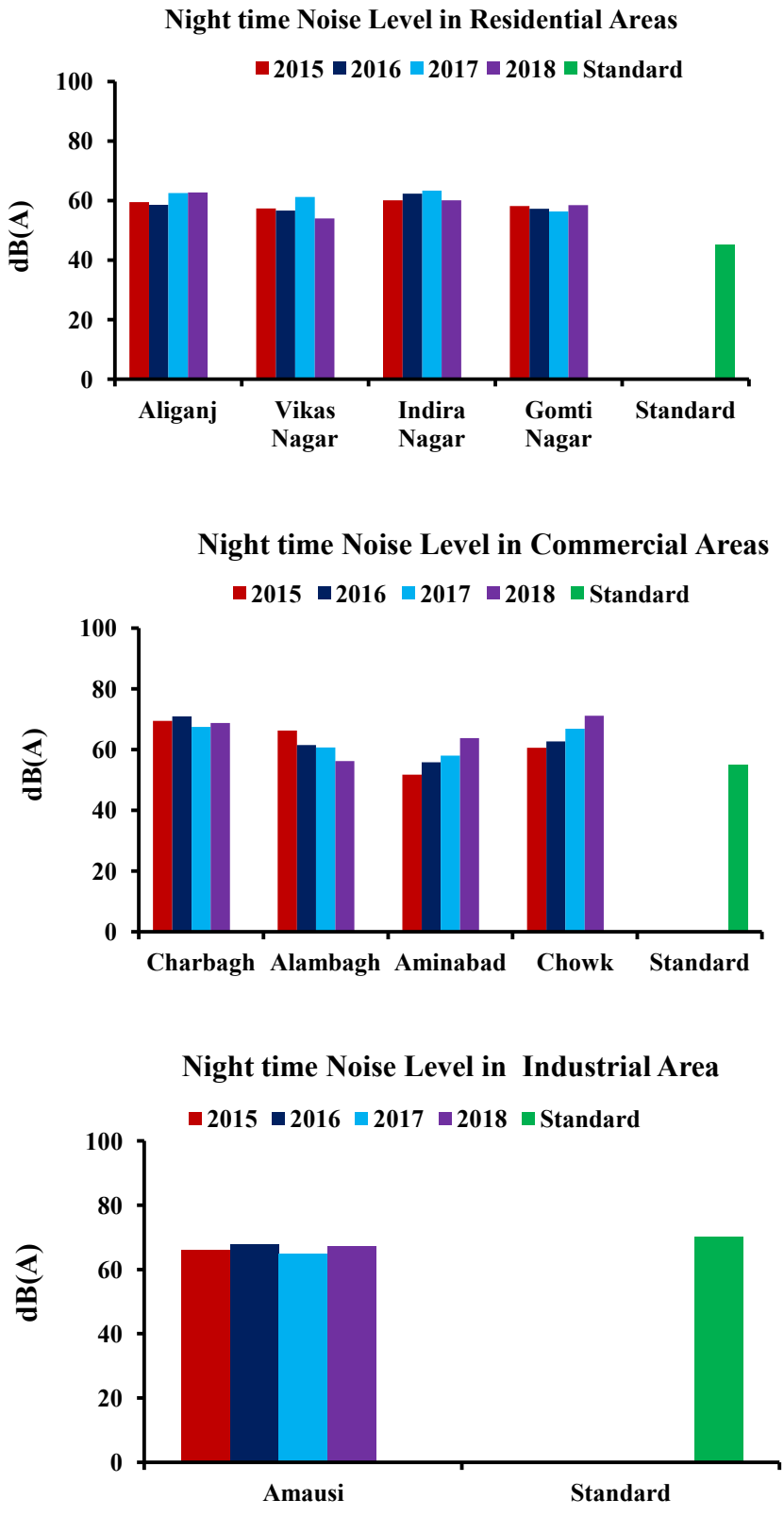

Figure 8: Comparison of night time Noise Level dB(A) in different areas of Lucknow city (2015-2018)

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 (NO_x) causes a wide variety of health and environmental impacts because of various compounds and derivatives in the family of nitrogen oxides, including nitrogen dioxide, nitric acid, nitrous oxide, nitrates, and nitric oxide. NO_2 is a reddish-brown gas with a pungent and irritating odour. It transforms in the air to form gaseous nitric acid and toxic organic nitrates. Nitrogen dioxide can have both acute and chronic effects on health, particularly in people with asthma. NO_2 causes inflammation of the airways.

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

It is known 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 properties of the PMs which depend on the level of associated trace metals, organic chemicals as well as the other pollutants. Overall, the effects/toxicity depends on the synergistic effects of physicochemical properties of PMs and environmental circumstances including receptors conditions. 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 damage 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)

NOx causes a wide variety of health and environmental impacts because of various compounds and derivatives in the family of NOx including NO_2, HNO_3, NO, nitrates and nitric oxide.

- Nitrogen dioxide (NO_2) is associated with mortality and a range of morbidity outcomes.
- NO_2 can be used as a marker of traffic proximity and convenient metric for modelling the health impacts of traffic pollution and evaluating abatement policies.
- Long term exposure to NO_2 may affect lung function and lowering the resistance to diseases such as pneumonia and influenza.
- Extremely high-dose exposure (as in a building fire) to NO_2 may result in pulmonary edema, diffuse lung injury and development of acute or chronic bronchitis.
- Industrial exposures to nitric oxide can cause unconsciousness, vomiting, mental confusion, and damage to the teeth.
- Exposure to low levels of nitrogen oxides in smog can irritate the eyes, nose, throat and lungs and can cause coughing, shortness of breath, fatigue, and nausea.

1.5.4 Health Effects of Trace elements

Lead (Pb)

- Lead is 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.

1.5.4 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.

In the present study, the concentration of SO_2 and NOx were found to be below permissible limit (80 µg/m^3) 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.

1.6 CONCLUSIONS

During pre monsoon (April-May), 2018 we have monitored air pollutants such as PM_{10}, $PM_{2.5}$, SO_2, NO_x and trace metals for the assessment of ambient air quality.

Besides, we have also monitored noise level during day and night time at 9 locations. The results revealed as follows-

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

- The mean level of fine particles ($PM_{2.5}$) at all the monitoring locations of residential, commercial and industrial areas was higher than the NAAQS.

- The observed values of sub fractions of particles were found to be higher in commercial place. Presently there is no guideline/NAAQS for these sub-fractions of fine particles. There is considerable toxicological evidence of potential detrimental effects of these sub-fraction particles on human health.

- The concentration of gaseous pollutants, SO_2 and NO_x were below the prescribed NAAQS (80 $\mu g/m^3$) at all the locations but showed slightly lower values compared to previous year with little exception. The lower values especially in the Alambagh, Charbagh areas might be due to low volume to heavy traffic on the metro construction route than the previous years.

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

- Overall results indicate that all the air pollutants measured showed slightly slightly decreasing trend. The cause might be due to weather conditions like rainfall during end of April and early May, high temperature and wind speed.

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

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

1.7 RECOMMENDATIONS FOR MITIGATION OF AIR POLLUTION

1. Widening of major roads of the city as far as possible.
2. Suitable modification on crossing for smooth traffic flow.
3. Clearing the encroachments for smooth traffic flow.
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. Development of subsidized public mass transport (Metro, Monorail etc.) 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. Development of residential complexes at the periphery of the city with all facilities to reduce population density in 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 vehicles.
17. Promoting solar energy as an alternate to D.G. sets.
18. Replacement of pressure horns by low noise horns.
19. **Installment of heavy dust removal system at major traffic point which may be operated during peak hours.**

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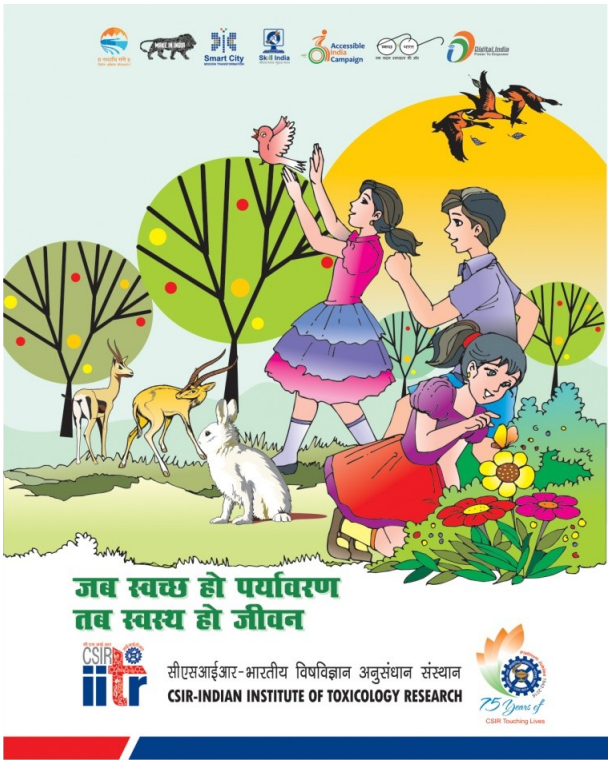
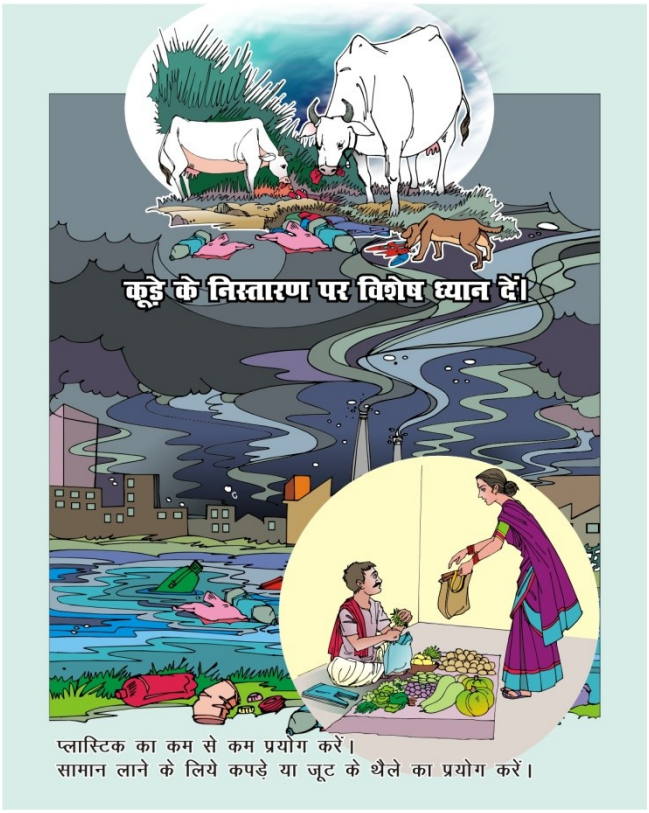
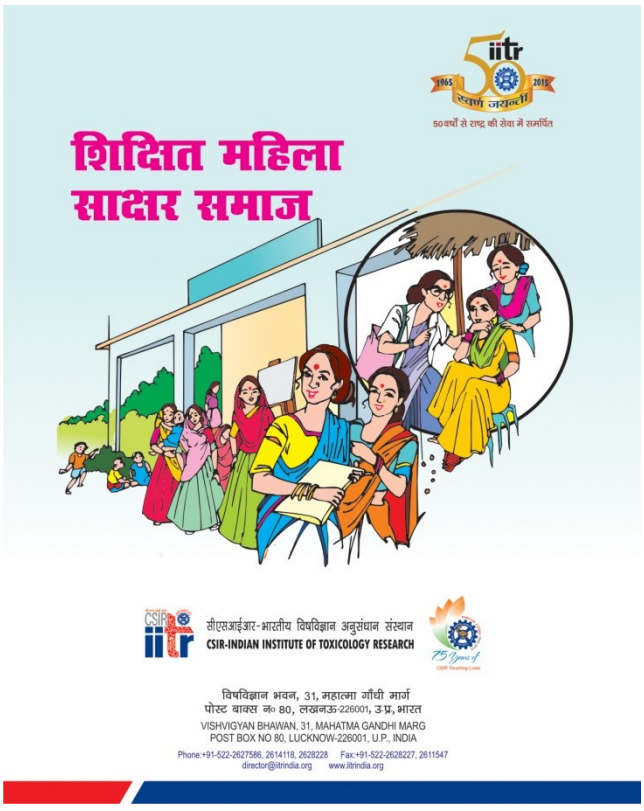
Annexure 1

Brochure – Public Awareness for Clean Environment




कूड़े के निस्तारण पर विशेष ध्यान दें।
प्लास्टिक का कम से कम प्रयोग करें।
सामान लाने के लिये कपड़े या जूट के थैले का प्रयोग करें।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सीएसआईआर-भारतीय विषविज्ञान अनुसंधान संस्थान
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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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