

Assessment of Ambient Air Quality of Lucknow City

Post-Monsoon 2022





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Salient Features of the Study Area: Lucknow City

❖ Geographical Position	: 26° 52' N Latitude 80° 56' E Longitude 128 m above Sea Level
❖ Area	: 310 sq. km.
❖ Population	: 2815033 as per 2011 Census
❖ Projected Population	: 65 lakhs as per Master Plan 2031
❖ Climatic condition	: 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 number as on 31/03/2022	: 2650286
❖ Growth of Vehicles over 2020-2021	: 5.4%
❖ Total No. of Fuel Filling Stations (Petrol/Diesel/CNG)	: 159
❖ Consumption of Fuel:	
• Diesel	: 157220 kL
• CNG	: 69295471 kg
• Petrol	: 207417.5 kL
❖ Major Sources of Pollution	: Automobiles, D.G. Sets Biomass burning Construction activities Dry sweeping and resuspension of road dust
❖ Parameters Monitored	: PM ₁₀ , PM _{2.5} , SO ₂ , NO ₂ and Noise Levels
❖ Study Conducted by	: Environmental Monitoring Division CSIR-IITR, Lucknow

1.0 SUMMARY

*The Post-Monsoon, 2022 ambient air quality assessment for Lucknow city was carried out by the Environmental Monitoring Division of CSIR Indian Institute of Toxicology Research, Lucknow during October 27 – 31, 2022. Air quality status was evaluated through monitoring and assessment of some of critical and health affecting air pollutants like 1. **Respirable Suspended Particulate Matter:** PM_{10} , cut off size $\leq 10 \mu m$; and **Fine Particulate Matter:** $PM_{2.5}$, cut off size $\leq 2.5 \mu m$; 2. **Indicator Gases:** Sulphur dioxide (SO_2) and Nitrogen dioxide (NO_2); and 3. **Noise levels** at 9 representative locations which are grouped into 3 categories viz., i. **Residential area**, ii. **Commercial area** and iii. **Industrial area.***

The 24 hr concentrations of PM_{10} ranged from $131 \mu g/m^3$ to $354 \mu g/m^3$ with an average of $221.1 \mu g/m^3$ while in case of $PM_{2.5}$, the 24 hr concentrations ranged from $98 \mu g/m^3$ to $201 \mu g/m^3$ with an average of $141.1 \mu g/m^3$. Irrespective of the locations, the average values of PM_{10} and $PM_{2.5}$ were found to be above the permissible limits of $100 \mu g/m^3$ for PM_{10} and $60 \mu g/m^3$ for $PM_{2.5}$ prescribed by Central Pollution Control Board, New Delhi. However, the values of PM_{10} and $PM_{2.5}$ increased by 20.5% and 56.7 % compared to the levels measured during Post-monsoon 2021.

The 24 hr concentrations of SO_2 ranged from 12.3 to $38.4 \mu g/m^3$ with an average of $18.76 \mu g/m^3$ while the 24 hr concentrations of NO_2 ranged from 20.7 to $42.3 \mu g/m^3$ with an average of $29.6 \mu g/m^3$. The values of SO_2 and NO_2 increased by 48.6 % and 21.4 %, respectively. However, the average values of SO_2 and NO_2 were well below the permissible limits of $80 \mu g/m^3$ for both SO_2 and NO_2 prescribed by CPCB, New Delhi (NAAQS-2009).

The day time and night time noise levels ranged from 45.9 to 76.7 dB(A) and 41.0 to 76.4 dB(A) in residential areas and from 53.7 to 89.4 dB(A) and 47.1 to 83.2 dB(A) in commercial areas respectively. These measured values were above their respective day time standard of 55 dB(A) and night time standard of 45 dB(A) for residential areas and 65 dB(A) and 55 dB(A) for commercial areas respectively as per NAAQS. At Amausi Industrial area, the day time and night time noise levels were 82.5 dB(A) and 81.2 dB(A) respectively. The values are below the national standard of 75 dB(A) for day time and 70 dB(A) for night time recommended for Industrial areas.

The present study reveals that the levels of pollutants like inhalable particulate matter, gases, and noise are gradually increasing due to the fact that air quality monitoring of Post-monsoon, 2022 was actually held at the beginning of winter season and immediate next days of Diwali as well as Chhat-puja days with function of peaked vehicular movements in the city. Therefore, the emissions from Diwali combustions and accelerated transport activities added extra load of particle pollution to the city atmosphere.

1.1 INTRODUCTION

The Earth's atmosphere is a mixture of gases; where nitrogen and oxygen are present in a ratio of ~78% and ~21%; the remaining 1% consists primarily of 0.9% argon, a noble gas. In addition, 0.1% is a mix of trace gases consisting of neon, carbon dioxide, methane, water vapour etc. whose concentration is subject to change owing to various natural and anthropogenic phenomenon. Apart from these several other components also make up the Earth's atmosphere such as aerosols, suspended particles of various diameters, certain gases such as ozone, oxides of sulphur and nitrogen, various hydrocarbons, microbial entities and very many other less defined components. Oxygen is essential to sustain life on Earth whereas nitrogen is key to growth of both plants and animals. Any components present in the air, other than those naturally defined, or at places where they should not be, or at concentrations above background levels are categorized as contaminants. Any contaminants that are causatives of undesirable impacts on humans and the environment are classified as pollutants.

In this context the Air (Prevention and Control of Pollution) Act, 1981 states that "air pollutant means any solid, liquid or gaseous substance (including noise) present in the atmosphere in such concentration as may be or tend to be injurious to human beings or other living creatures or plants or property or environment", and that "air pollution means the presence in the atmosphere of any air pollutant". The air pollution spike tends to increase the morbidity and mortality rates due to respiratory health issues. Not all contaminants are pollutants as their concentrations tend to be too low to cause detrimental impacts; nonetheless all pollutants are contaminants first.

Meteorological factors play a major role in influencing concentration of air pollutants at ground level. Temperature, wind speed, wind direction, solar intensity, humidity, precipitation etc are the key governing meteorological parameters that affect air dispersion, dilution, deposition and physico-chemical transformations from source to receptor. Smaller and unstable compounds and particles tend to stay in the atmosphere for longer durations as compared to larger and stable ones. Pollutant release into the atmosphere can be from point sources such as power stations and industries, line sources such as vehicular exhaust and fugitive sources such as gases emanating from a



solid waste dump, fumes from fuel stations, roadside dust entrainment etc. The fate of all these pollutants is often guided by atmospheric reactions with each other and as a consequence of micro-meteorology of each pollutant.

This year, owing to extended monsoon season, rainfall was experienced till the first week of October 2022, causing a ‘washout effect’ on air pollutants and lowering their concentrations. In further days too, humidity levels remained high leading to sinking of the moisture adsorbed particulates to the ground level and lowering their atmospheric concentrations. Amidst such meteorological conditions, an early Diwali was also observed on the 24 th of October 2022 in India. Pollutant concentrations remained low owing to clear weather conditions and warm temperatures. In contrast, the decline in number of active cases affected by the COVID-19 virus and subsequent relaxation in restrictions on public gatherings, marketing and celebrations, has led to increment in vehicular traffic and consequent increase in pollutant concentrations. In essence, the cumulative impact of the pollutant wipe-out owing to rains and increment in activities owing to relaxation in COVID norms thereof, set the background for pollutant concentration in the post monsoon season in Lucknow city.

The UP-state capital Lucknow has seen increasing air pollution because of increasing vehicular number, population density and urban boundaries to encompass neighbouring regions. CSIR–Indian Institute of Toxicology Research (IITR) has been conducting air pollution study for Lucknow city for 24 years (i.e, since the year 1997) intended towards to improve the public awareness, support pollution control authorities to implement interventions to limit pollution levels and protection of public health. With this rationale, the post-monsoon random survey of air pollution levels in Lucknow city was carried-out continuously and simultaneously at 9-sampling sites covering residential, commercial and industrial areas. The study conducted as Phase-I: Diwali survey (pre-Diwali, Diwali and post-Diwali days – October 23-25, 2022) and Phase-II: Post-monsoon (i.e., October 27 to October 31, 2022).

Following objectives are in consideration for the post-monsoon, 2022 air pollution study in Lucknow:

- *To measure the day and night time ambient concentrations of particulates (PM_{10} & $PM_{2.5}$) and gases (SO_2 & NO_2) pollutants and Noise-levels*
- *To examine the status and trends of air pollution over the years in Lucknow city*
- *To develop the air quality database for post-monsoon season and impart state administrators for prioritising action plans to reduce the air pollution levels in city*
- *To create public awareness on the current status of air quality in Lucknow city.*

Vehicular and fuel consumption inventory for Lucknow city were carried out and primary information collected from RTO as on March 31, 2022 which showed increase of 5.4 % from last year 2021-22 in **Table 1**. The total number of CNG & electricity bus services of UPSRTC by 2022 is 69 & 97 respectively (**Table 2&3**). Different oil and gas companies provided total number of fuel outlets (petrol, diesel & CNG) in Lucknow are 159 (**Table 4**). Consumption of fuel comparisons between 2021 and 2022 years are presented in **Table 5** and it is found the consumption of petrol, CNG and LPG increased to 4.43%, 157.98 % respectively while diesel and LPG consumption were decreased to 11% and 3.1% by 2022. **Table 6** illustrates the change in CNG vehicle number in Lucknow.

Table 1: Comparison of Vehicle Numbers in Lucknow

S. No.	Type of Vehicles	No. of Registered Vehicles as on 31 st March		Increase in %
		2021-22	2020-21	
1.	Multi Articulated	7537	6648	13.4
2.	Light, Medium & Heavy Weight Vehicles (Four Wheelers)	56908	51603	10.3
3.	Light Commercial Vehicles (Three Wheeler)	3921	3798	3.2
4.	Buses	4794	4383	9.3
5.	Omni Buses	547	489	11.9
6.	Taxi	51165	37993	34.7
7.	Light Motor Vehicles (Passenger)	11139	10557	5.5
8.	Two Wheelers	1931469	1860778	3.7
9.	Motor Cycle on Hire	409	384	6.5
10.	Car	353100	330596	6.8
11.	Jeep	126222	105707	19.4
12.	Tractors	29169	28022	4.1
13.	Trailers	2103	1989	5.7
14.	Others	71803	71514	0.1
Increase in total number of vehicles		2650286	2514461	5.4

Source: RTO, Lucknow, 2022

Table 2: Details of Lucknow CNG City Bus Service (Gomti Nagar Depot), 2022

S. No.	Route No.	To and Fro	No. of Buses	Frequency (minutes)
1	101	Goyal institute-Ramswaroop college –BBD- Dayal Regidency-Matiyai tiraha-Petrol Pump- Chinhat turn-kathota chauraha-Amity Univrsity-Honeyman Chauraha- Judicial Training Research Institute-Husadiya Chauraha-Malik timber-Ptrkar puram-Manoj pandey Chauraha-Shankar Chauraha- Dayal Adda MM Malviya Turn-Tikuniya Park-Daynik Jagran-Sikandarbagh- Jawahar Bhawan-Shakti bhawan –Incometax Office- GPO-Bapu bhawan-Barlington- Hussainganj-Vikasdeep-KKC- Charbagh-Charbagh Bus station.	9	09
2	103	Charbagh-KKC-Vikasdeep- Hussainganj- Barlington-Bapu Bhawan- GPO- Incometax office-Shakti bhawan- Jawahar Bhawan- Sikandarbagh- Gokhle Marg- Papermill Colony-Nishatganj- Gol Market- Badhshah nagar- Shaktinagar Dhaal-Lekhraj- Neelgiri- Bhootnath- HAL- Aravali turn- Polytechnic-New High coart- Kamta- Chinhat- Matiyari Chauraha- Shivpuri-TATA Motors- Chakkar Chauraha- Sharda Nahar- Samarpan Hospital-	9	09
3	202	Industrial area- Scooter India-Gauri vihar- Hydle Colony- Sainik School- Shanti Nagar- Nadarganj – Airport Bagiya No. 3-Bagiya No. 2- Transport Nagar- Aurangbad- Ramabai Maidan-Shubham South City- Uttarethiya- Vrindavan Yojna- Awadh Shilp Gram- Delhi Public School- Awadh Shilp Gram-2. □ CMS- Ahimamau- Suda Office- Cricket Stadium- Delhi Public School- Homegaurd Office- Husadiya- Gomtinagar Bus Station-High Coart–Kamta.	34	03
4	401	Integral University- P.S. Gudamba- Pahadpur Tiraha- Gayatri Mandir- Tedhi Puliya- Chandra sweet house- Lohiya Nagar Turn- Lekharaj Panna- PNB Turn- K. K Palace- Vikasnagar-Rahim Nagar- wireless Chauraha- Mahanagar Bayaz- Gol market- Badshahnagar- Nishatganj- Paper mill Colony- Gokhley Marg Sikandarbag- Jawahar Bhawan- Shakti Bhawan- Income tax office- GPO- Bapu Bhawan- Barlingtn- Hussainganj-Vikasdeep- KKC- Charbagh – Mavaiya- Alambagh- P.S. –Tedhi puliya- Alambagh Bus station- Ajanta hospital- Alambagh Chauraha- Ramnagar- Pooran Nagar- Singarnagar- Awadh Hospital- Devpur Para- Para Mod- Sindhi Colony- Hanskheda-Kashiram Yojna.	5	16

5	402	Integral University- P.S. Gudamba- Pahadpur Tiraha- Gayatri Mandir- Tedhi Puliya- Chandra sweet house- Lohiya Nagar Turn- Lekharaj Panna- PNB Turn- K. K Palace- Vikasnagar- Rahim Nagar- wireless Chauraha- Mahanagar Bayaz- Gol market- Badshahnagar- Nishatganj- Paper mill Colony- Gokhley Marg Sikandarbag- Jawahar Bhawan- Shakti Bhawan- Income tax office- GPO- Babu Bhawan- Barlingtn- Hussainganj- Vikasdeep- KKC- Charbagh – Mavaiya- Alambagh- P.S. –Tedhi puliya- Alambagh Bus station- Ajanta hospital- Alambagh Chauraha- Ramnagar- Pooran Nagar- Singarnagar- Awadh Hospital- Barabirwa- Burgawan-BSNL Trainng Insitute- Prem Plaza- Ashiyana Chauraha- P.S Ashiyana- Qilagaon Chauraha—Qila Chauraha- Rajnikhand Turn- Rajnikhand.	12	12
		Total	69	

Table 3: Details of Lucknow Electric City Bus Service (Dubagga Depot), 2022

S. No.	Route No.	To and Fro	No. of Buses
1	105	Raja ji Puram – Charbagh – Nishatganj – Polytechnic – kamta- Chinhat- Awadh Bus Station (Kamta) – BBD	14
2	301	Scooter India – Krishna Nagar – Awadh Hospital – Alambagh – Mawaiyya – Charbagh – GPO – Engg. College	22
3	502	Scooter India- Awadh Hospital- Alambagh- Charbagh- GPO – Sikanderbagh chauraha- Polytechnic- Awadh Bus Station (Kamta) – Goyal Ins.	5
4	801	Balaganj - Dubagga – Bhitauli– New High Coart- Polytechnic – Virajkhand	16
5	801-E	Balaganj - Dubagga – Bhitauli – Polytechnic – Virajkhand Bus Station	8
6	1102-E	Ghantaghar- Chawk- Dubagga- Sitapur Bypass- Kasmandi- Navipanah- mall.	12
7	1201-E	Dubagga Dipo- Sitapur Bypass- Career Dental College. Dental College – Dubagga- Awadh Hospital – SGPGI- Mohanlalganj.	20
		TOTAL	97

Table 4: Fuel Outlets in Lucknow City

S.No.	Agency	Number of outlets as on 31 st March 2022
1	Indian Oil Corporation (IOC)	55
2	Bharat Petroleum Corporation Ltd. (BPCL)	30
3	Hindustan Petroleum Corporation Ltd. (HPCL)	42
4	Compressed Natural Gas Stations (CNG)	32
Total		159

Source: Indian Oil Corporation (IOC), Lucknow; Bharat Petroleum Corporation (BPCL); Hindustan Petroleum Corporation (HPCL); Green Gas Limited, Lucknow, 2022.

Table 5: Fuel Consumption in Lucknow City

S. No.	Agency	Petrol in kL			High Speed Diesel in kL			CNG in Kg		
		Apr. 21 to Mar. 22	Apr. 20 to Mar. 21	% Change	Apr. 21 to Mar. 22	Apr. 20 to Mar. 21	% Change	Apr. 21 to Mar. 22	Apr. 20 to Mar. 21	% Change
1.	IOC	98433	85316	15	71027	66726	6.44	20313039	11563212	75.66
2.	BPCL	64139	48883	31.20	42769	33984	25.85	90000	918151	-90.19
3.	HPCL	44845.5	56950	-26.99	43424	75950	-25.85	3075300	1840921	67.05
4.	Green Gas	-	-	-	-	-	-	40395998	12538366	222.12
Total		207417.5	198607	4.43	157220	176660	-11	69295471	26860650	157.98
LPG in Ton										
5.	IOC	Apr. 21 to Mar. 22	Apr. 20 to Mar. 21	% Change	-	-	-	-	-	-
		1007	1040	-3.1	-	-	-	-	-	-

Source: Indian Oil Corporation (IOC), Lucknow; Bharat Petroleum Corporation (BPCL); Hindustan Petroleum Corporation (HPCL); Green Gas Limited, Lucknow, 2022.

Table 6: Distribution of CNG Vehicles

S. No.	Vehicles	Number		% of Change
		2021-22	2020-21	
1	Auto Rickshaws	4343	4343	-
2	Tempo Taxi	2575	2575	-
3	Buses (UPSRTC)	260	260	-
4	Buses (Private)	40	40	-
5	School Buses	1745	1557	12.07
6	School Van	3117	2231	39.71
7	Private Vehicles	472	472	-
8	Private Cars	30015	24539	22.31
	Total	42567	36017	18.18

Source: RTO, Lucknow; Green Gas Limited, Lucknow, 2022.



1.2 METEOROLOGICAL CONDITIONS

Meteorology plays a major role in dispersion and dilution of air pollution. Meteorological condition during the study period (i.e. October 27th to October 31st 2022) has been measured in Lucknow and illustrated in [Figure 1](#). Relative humidity is in the range of 43-96%, whereas temperatures are in the range of 17-33° C. Windrose shows that the predominant wind direction is from South to North. Calm winds are significant which are about 21.74% of the times due to beginning of winter season and maximum wind speed is observed in the range 0.5-8.8 m/s.

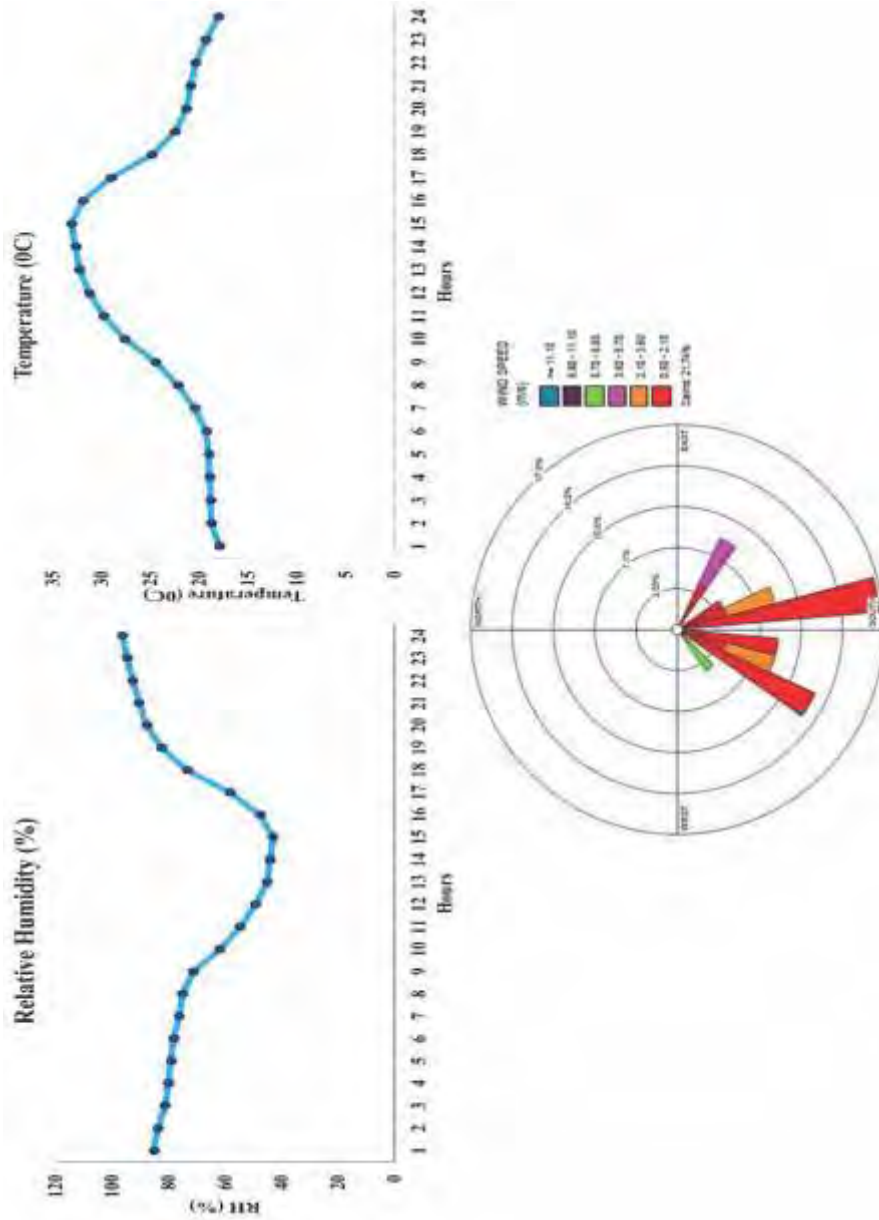


Figure 1: Meteorological conditions during the survey period in Lucknow city

1.3 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 Post-monsoon 2022 study as summarized in Table 7 and Figure 2 and adopted methodologies are given in Table 8. A total of eight samplings were carried out during the months of October, 2022.

Table 7: 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	Commercial cum traffic
9	Amausi	Industrial

Table 8: 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	Noise Level	1 hour	The measurement of noise level was carried out during the day (6 AM to 10 PM) and night time (10 PM to 6 AM) by Noise Level Meter



Figure 2: Ambient Air Pollution Monitoring at 9 Locations in Lucknow City

1.4 RESULTS

The detailed results of air quality monitoring during the Post-monsoon, 2022 period are presented in [Table 9](#) and [Figure 3-4](#).

1.4.1 Respirable Suspended Particulate Matter (RSPM or PM₁₀)

In residential areas (Aliganj, Vikas Nagar, Indira Nagar and Gomti Nagar), the 24 hours concentrations of PM₁₀ were in the range of 164 $\mu\text{g}/\text{m}^3$ to 225 $\mu\text{g}/\text{m}^3$ with an average of 195.5 $\mu\text{g}/\text{m}^3$. The average concentration of PM₁₀ was observed highest at Indiranagar (214 $\mu\text{g}/\text{m}^3$) among the residential areas.

In commercial areas (Charbagh, Alambagh, Aminabad and Chowk) the concentrations of PM₁₀ were in the range of 198 $\mu\text{g}/\text{m}^3$ to 354 $\mu\text{g}/\text{m}^3$ with an average of 264.7 $\mu\text{g}/\text{m}^3$ respectively. The average concentration of PM₁₀ was observed highest at Charbagh (330 $\mu\text{g}/\text{m}^3$) among the commercial areas.

In industrial area (Amausi), the average concentration of PM₁₀ was 149 $\mu\text{g}/\text{m}^3$. However, in all locations PM₁₀ levels were exceeded the prescribed National Ambient Air Quality Standard (NAAQS) of 100 $\mu\text{g}/\text{m}^3$.

1.4.2 Fine Particulate Matter (PM_{2.5})

In residential areas (Aliganj, Vikas Nagar, Indira Nagar and Gomti Nagar), the 24 hours concentrations of PM_{2.5} were in the range of 105 $\mu\text{g}/\text{m}^3$ to 156 $\mu\text{g}/\text{m}^3$ with an average of 125.5 $\mu\text{g}/\text{m}^3$. The average concentration of PM_{2.5} was observed highest at Indiranagar (143 $\mu\text{g}/\text{m}^3$) among the residential areas.

In commercial areas (Charbagh, Alambagh, Aminabad and Chowk) the concentration of PM_{2.5} was in the range of 126 to 201 $\mu\text{g}/\text{m}^3$ with an average of 166.0 $\mu\text{g}/\text{m}^3$ respectively. The average concentration of PM_{2.5} was observed highest at Charbagh (192 $\mu\text{g}/\text{m}^3$) among the commercial areas.

In industrial area (Amausi), the average concentration of $PM_{2.5}$ was $104\mu g/m^3$. However, in all locations $PM_{2.5}$ levels were exceeded the prescribed National Ambient Air Quality Standard (NAAQS) of $60\mu g/m^3$.

1.4.3 Sulphur dioxide (SO_2)

In residential area (Aliganj, Vikas Nagar, Indira Nagar and Gomti Nagar), the levels of SO_2 was in the range of 12 to $26\mu g/m^3$ with an average of $19.9\mu g/m^3$. In commercial areas (Charbagh, Alambagh, Aminabad and Chowk) the concentrations of SO_2 were in the range of 24 to $38\mu g/m^3$ with an average of $31.1\mu g/m^3$. In industrial area (Amausi), the mean level of SO_2 was $14.1\mu g/m^3$.

However, all the values of SO_2 were well below the prescribed NAAQS of $80\mu g/m^3$ for all the locations.

1.4.4 Nitrogen dioxide (NO_2)

In residential areas (Aliganj, Vikas Nagar, Indira Nagar and Gomti Nagar) the 24 hours concentration of NO_2 was in the range of 21 to $34\mu g/m^3$ with an average of $28.3\mu g/m^3$. In commercial areas (Charbagh, Alambagh, Aminabad and Chowk) the concentration of NO_2 was in the range of 26 to $42\mu g/m^3$ with an average of $32.5\mu g/m^3$. In industrial areas (Amausi), the average concentration was $23.9\mu g/m^3$.

However, all the values of NO_2 were within the prescribed NAAQS of $80\mu g/m^3$ for all the monitoring locations.

Table 9: Concentration ($\mu\text{g}/\text{m}^3$) of PM_{10} , $\text{PM}_{2.5}$, SO_2 and NO_2 during Post-Monsoon (October 27-Oct 31, 2022)

Location	PM_{10} (RSPM)			$\text{PM}_{2.5}$			SO_2			NO_2		
	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
Residential												
Aliganj	182	199	192±16	113	128	119±23	12.3	18.9	15.2±1.4	24.1	29.4	27.8±5.1
Vikas Nagar	164	185	171±18	105	114	108±21	13.5	19.2	16.8±1.5	21.4	25.1	22.2±5.2
Indira Nagar	209	225	214±13	135	156	143±24	20.7	24.9	23.1±2.3	28.9	32.8	30.6±4.2
Gomti Nagar	195	209	205±24	130	139	132±27	19.8	26.4	24.6±1.3	25.7	34.2	32.4±6.8
Commercial												
Charbagh	316	354	330±23	184	201	192±28	28.1	35.1	32.3±1.4	32.9	36.9	33.1±5.1
Alambagh	198	210	209±28	126	150	138±32	26.9	31.8	29.7±1.2	28.4	34.8	30.8±4.5
Aminabad	208	228	214±24	133	162	145±34	24.5	30.2	27.9±1.9	26.2	29.2	27.5±4.7
Chowk	281	313	306±35	172	191	189±39	31.3	38.4	34.5±2.6	35.9	42.3	38.7±6.1
Industrial												
Amausi	131	152	149±19	98	111	104±22	12.7	17.2	14.1±1.7	20.1	24.7	23.9±4.8
NAAQS	100			60			80			80		
WHO Guidelines	50			25			20			40*		

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

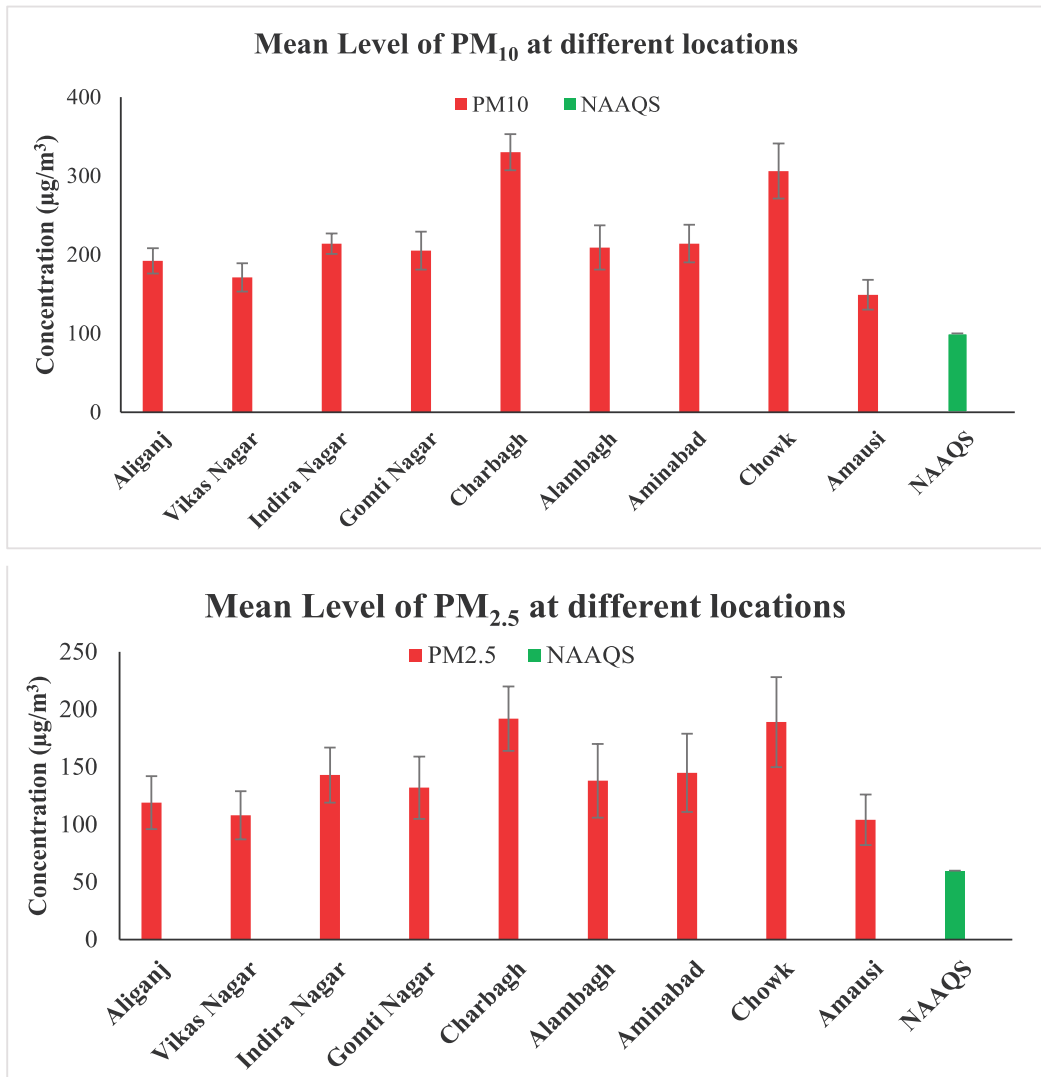


Figure 3: Concentration (µg/m³) of PM₁₀ and PM_{2.5} in different areas of Lucknow city during Post-Monsoon Season (2022) compared with prescribed National Ambient Air Quality Standard (NAAQS)

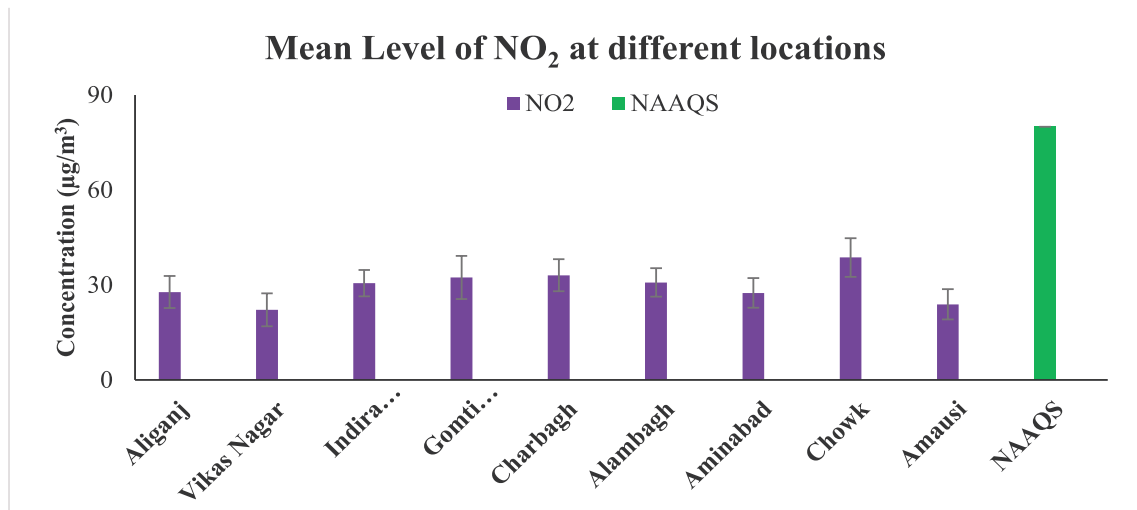
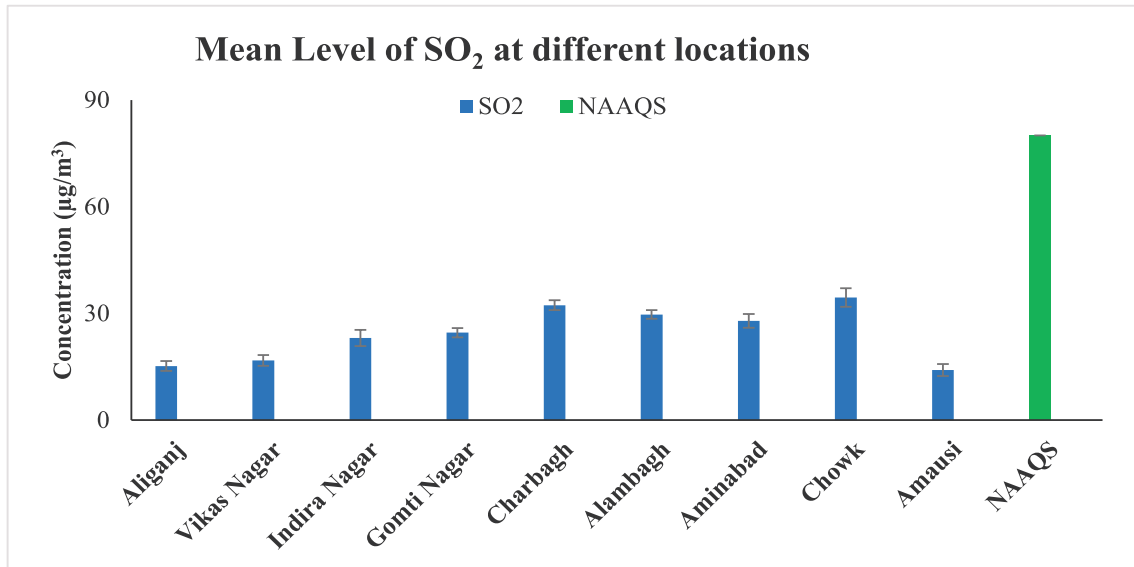


Figure 4: Concentration ($\mu\text{g}/\text{m}^3$) of SO₂ and NO₂ in different areas of Lucknow city during Post-monsoon season (2022) compared with prescribed National Ambient Air Quality Standard (NAAQS)

1.4.5 Noise Level

The noise monitoring data recorded during the Post- monsoon period (October, 2022) is presented in **Table 10**. Among residential areas, the day and night time noise levels were recorded with the range from 45.9 to 76.7 and 41.0 to 76.4 dB(A) respectively. All the values were significantly higher than the prescribed national limits of 55 and 45 dB (A) for day and night time respectively.

Among commercial and traffic area, the day and night time noise levels were recorded with the range from 53.7 to 89.4 and 47.1 to 83.2 dB(A) respectively. Noise level at all the commercial sites during day and night time were significantly higher than the prescribed national limits of 65 dB(A) and 55 dB(A) for day and night time respectively.

In industrial area Amausi, the day and night time noise levels were recorded 82.5 and 81.2 dB(A) respectively. Noise levels at industrial area were recorded higher than the NAAQS of 75.0 and 70.0 dB(A) respectively.

Table 10: Noise Level dB(A) during Day and Night Time for the Monitoring Period October 27 to 31, 2022

Location		Pre-Monsoon, 2022		Post-Monsoon, 2022	
		Day	Night	Day	Night
Aliganj	Min	48.8	43.9	50.0	42.3
	Max	78.1	68.9	71.0	62.0
	Avg. (Leq)	66.1	60.8	68.9	61.7
Vikas Nagar	Min	52.9	48.9	47.7	41.0
	Max	84.2	74.3	76.7	66.9
	Avg. (Leq)	63.8	63.6	71.2	59.3
Indira Nagar	Min	51.2	38.7	49.6	46.7
	Max	82.8	69.2	74.0	67.0
	Avg. (Leq)	73.2	62.5	73.8	63.8
Gomti Nagar	Min	58.2	41.2	45.9	49.2
	Max	79.1	71.2	75.7	76.4
	Avg. (Leq)	72.5	67.8	70.0	71.2
Standard at Residential Area		55.0	45.0	55.0	45.0
Charbagh	Min	56.2	56.1	58.1	66.2
	Max	85.1	78.1	89.4	83.2
	Avg. (Leq)	82.8	75.9	79.5	81.9
Alambagh	Min	49.4	46.2	54.1	47.1
	Max	76.5	69.2	83.0	79.0
	Avg. (Leq)	86.6	67.9	73.5	68.1
Aminabad	Min	61.2	47.1	53.7	54.0
	Max	84.2	72.1	85.0	77.5
	Avg. (Leq)	80	67.9	78.5	71.2
Chowk	Min	72.1	48.2	67.1	51.9
	Max	89.1	78.1	87.8	79.1
	Avg. (Leq)	79.9	74.6	80.4	69.5
Standard for Commercial Area		65.0	55.0	65.0	55.0
Amausi	Min	46.2	46.2	62.4	57.9
	Max	87.2	78.1	80.5	83.9
	Avg. (Leq)	81.3	72.9	82.5	81.2
Standard for Industrial Area		75.0	70.0	75.0	70.0
Minimum		63.8	60.8	68.9	56.8
Maximum		86.9	75.9	80.4	81.9
Mean of 9 Averages (Leq)		76.3	68.2	75.2	69.2
SD of 9 Averages (Leq)		7.4	5.1	4.0	8.1

#Leq- Equivalent continuous sound level

1.5 TRENDS OF AMBIENT AIR QUALITY IN LUCKNOW CITY

The observations of PM₁₀, PM_{2.5}, SO₂ and NO₂ for last 5 years (i.e., 2017 to 2021) Post-monsoon data have been compared with Post-monsoon 2022 to find out the prevailing trend of air pollution in Lucknow city (Figures 5-8). Slight changes in the values are attributed due to some local environmental phenomena, urban development and weather conditions.

1.5.1 Trend of PM₁₀ and PM_{2.5}

Figure 5 and Figure 6 indicate that the PM₁₀ and PM_{2.5} concentration was in decreasing trend till 2020, but it is in increasing trend from 2021 to 2022. The levels of PM₁₀ and PM_{2.5} at all the residential, commercial and industrial areas were relatively higher as compared to monitoring data of previous year 2021 and also exceeded the NAAQS.

1.5.2 Trend of SO₂ and NO₂

The levels of SO₂ and NO₂ during Post-monsoon since 2017 are presented in Figure 7 and Figure 8 for all the locations. SO₂ and NO₂ are in decreasing trend till 2020 while it is in marginal increasing from 2021 to 2022. In residential, commercial and industrial areas, higher concentrations of SO₂ were found compared to that of the previous year 2021. The concentration of NO₂ during Post-monsoon 2022 were observed slightly decreasing trend with respect to the concentration of previous year 2021. However, all the values of the present study were found to be lower than the NAAQS.

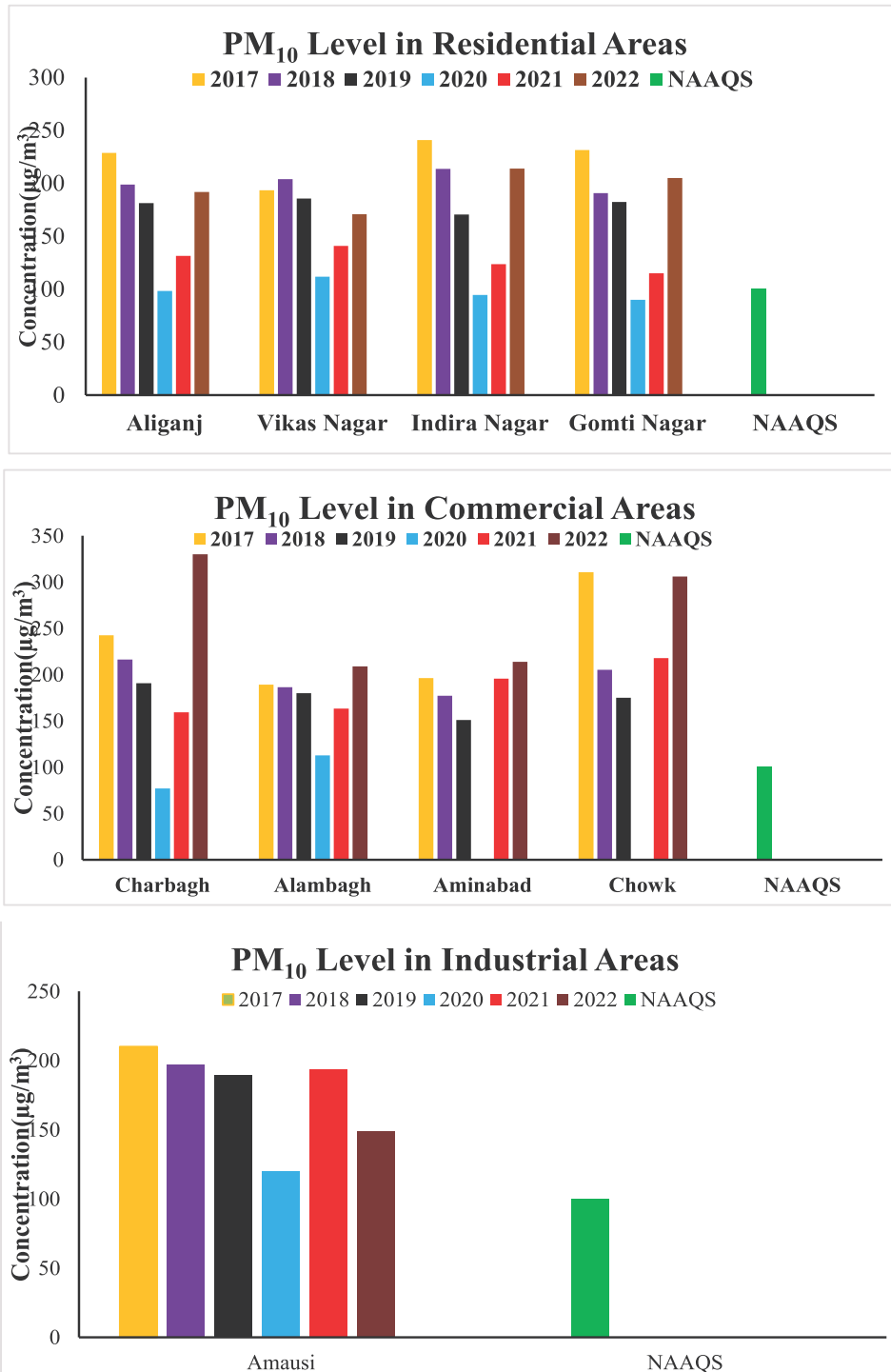


Figure 5: Concentration ($\mu\text{g}/\text{m}^3$) of PM₁₀ (RSPM) in Residential, Commercial and Industrial areas of Lucknow city during 2017 to 2022 (Post-monsoon) and compared with prescribed National Ambient Air Quality Standard (NAAQS)

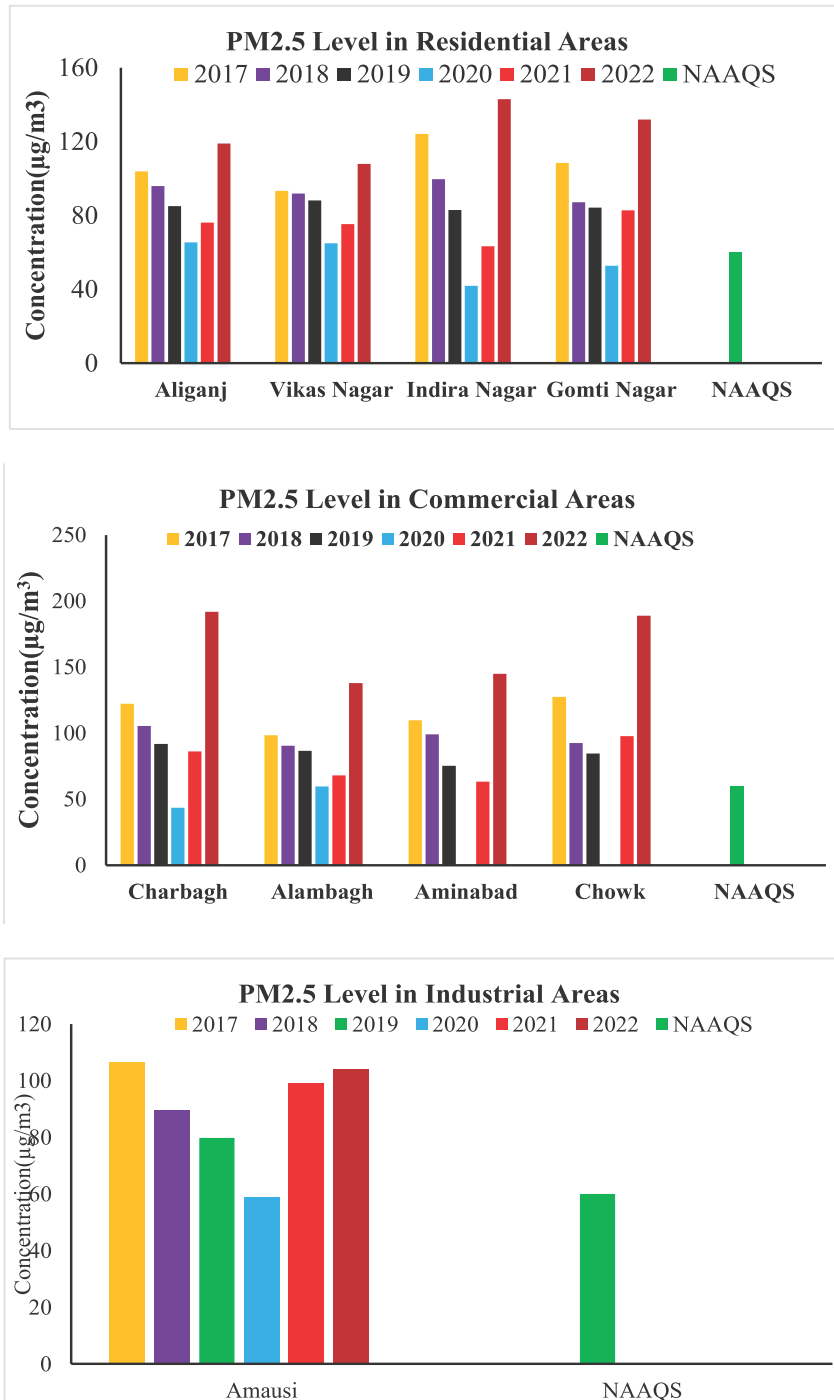


Figure 6: Concentration ($\mu\text{g}/\text{m}^3$) of $\text{PM}_{2.5}$ in Residential, Commercial and Industrial areas of Lucknow city during 2017 to 2022 (post-Monsoon) and compared with prescribed National Ambient Air Quality Standard (NAAQS)

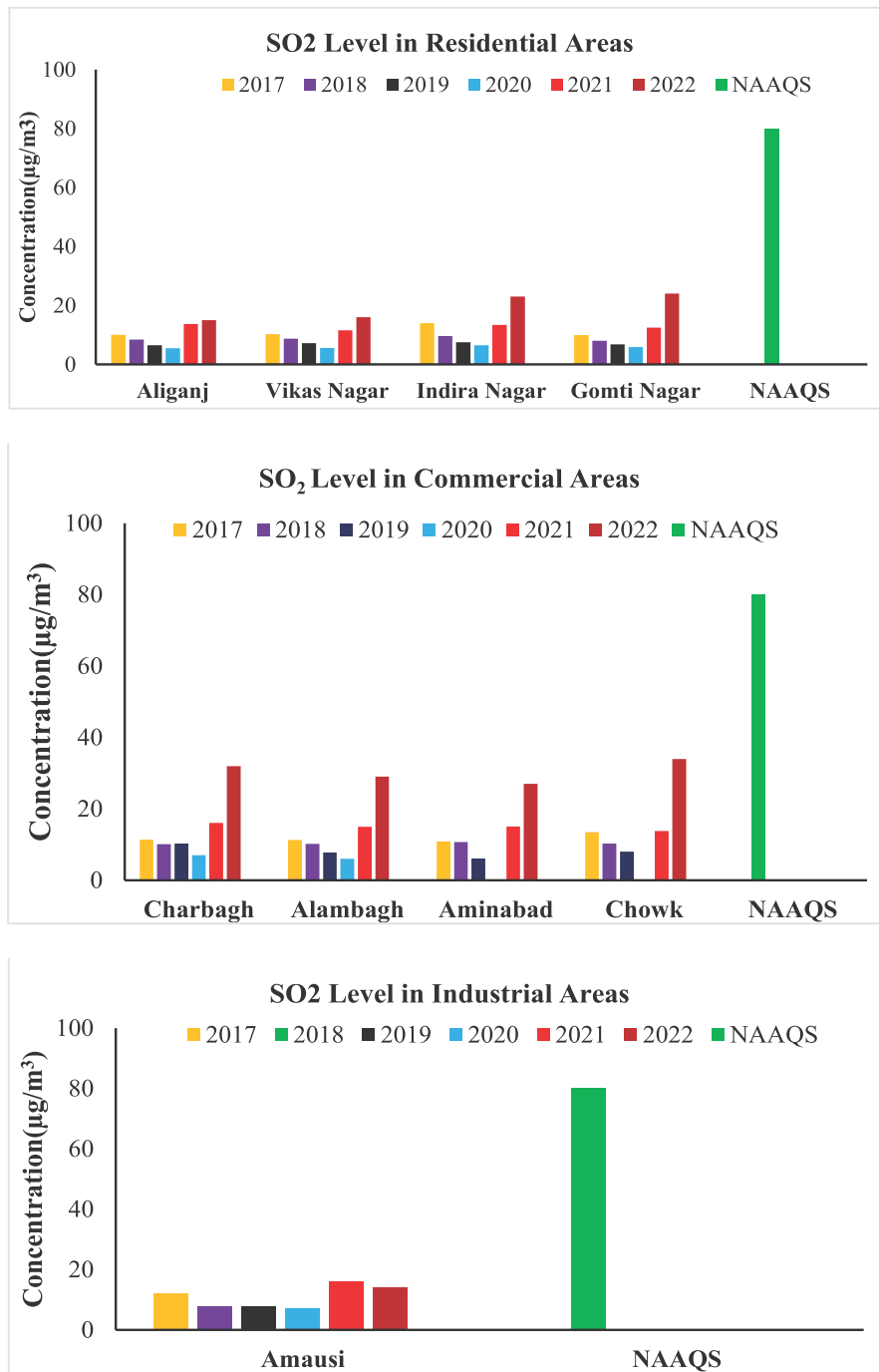


Figure 7: Concentration ($\mu\text{g}/\text{m}^3$) of SO_2 in Residential, Commercial and Industrial areas of Lucknow city during 2017 to 2022 (Post-monsoon) and compared with prescribed National Ambient Air Quality Standard (NAAQS)

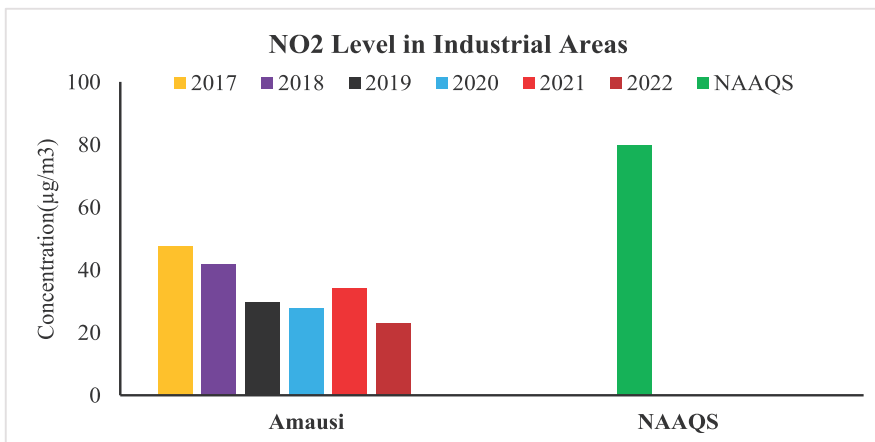
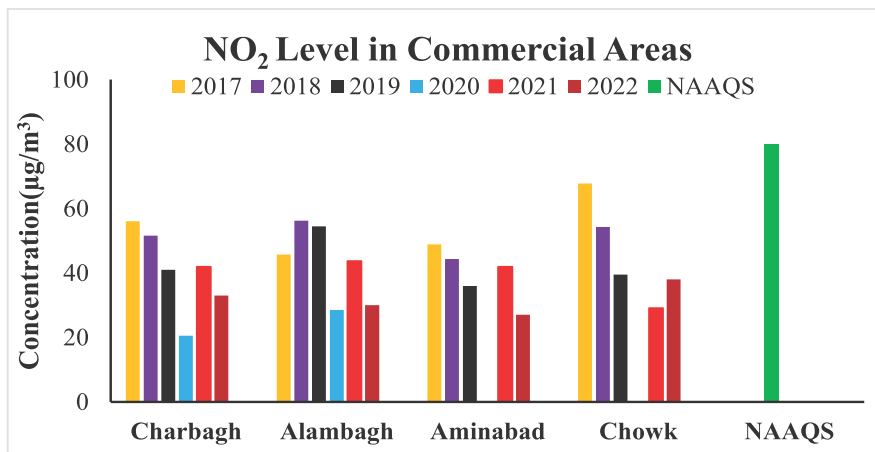
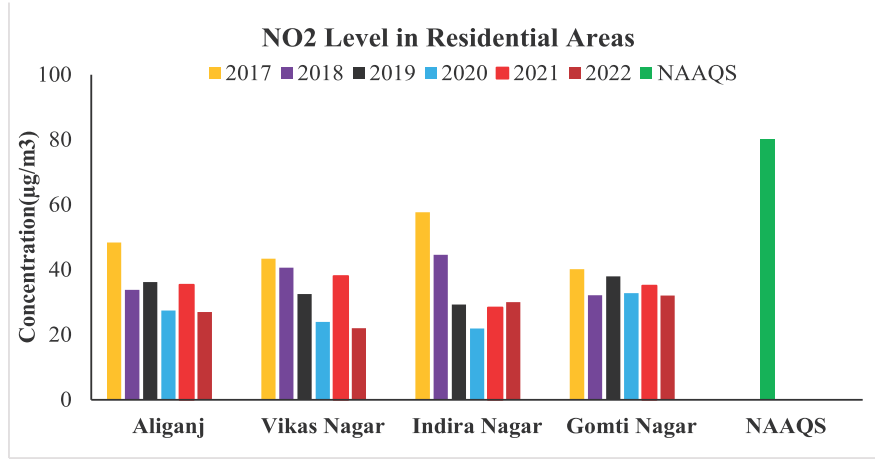


Figure 8: Concentration ($\mu\text{g}/\text{m}^3$) of NO₂ in Residential, Commercial and Industrial areas of Lucknow city during 2017 to 2022 (Post-monsoon) and compared with prescribed National Ambient Air Quality Standard (NAAQS)



1.5.3 Trend of Noise Level

In the present study Post-monsoon 2022 noise data were compared with the corresponding Post-monsoon data of the last 5-years i.e. 2017 to 2021 and the results are presented in [Figure 9 and 10](#). Noise pollution is the spread of unwanted sounds into the environment. Unwanted sounds have a range of mental health effects and other health problems like stress related illnesses, high blood pressure, speech interference, hearing loss and sleep disruption.

1.5.3.1 Day time Noise Level

All residential, commercial cum traffic and industrial areas showed slightly increasing trend over that of the previous year. The comparative trend analysis is presented in [Figure 9](#).

1.5.3.2 Night time Noise Level

All residential, commercial cum traffic and industrial areas showed increasing trend over that of the previous year. The comparative data are presented in [Figure 10](#).

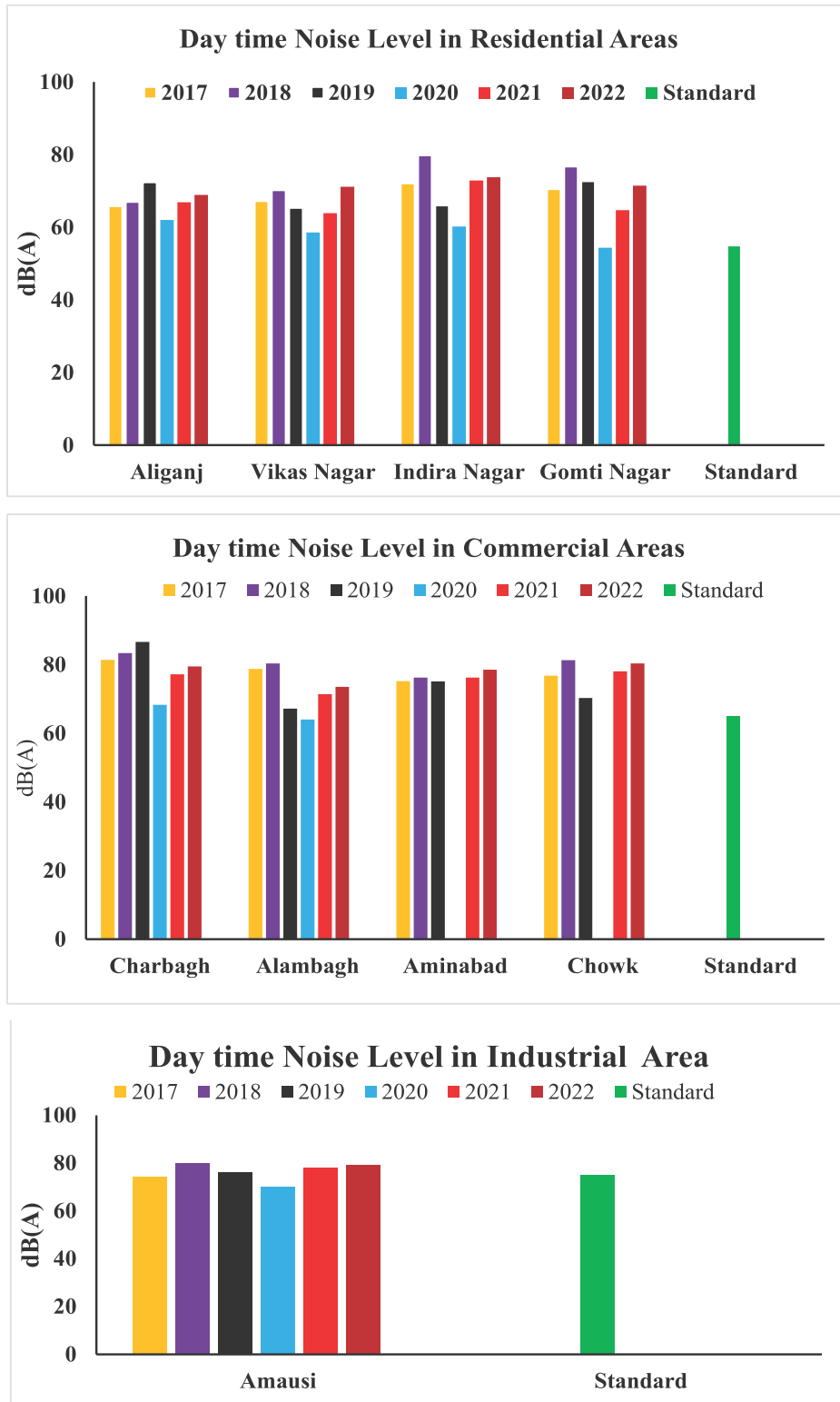


Figure 9: Comparison of day time Noise Level in dB(A) for different areas of Lucknow city (Post-monsoon 2017-2022)

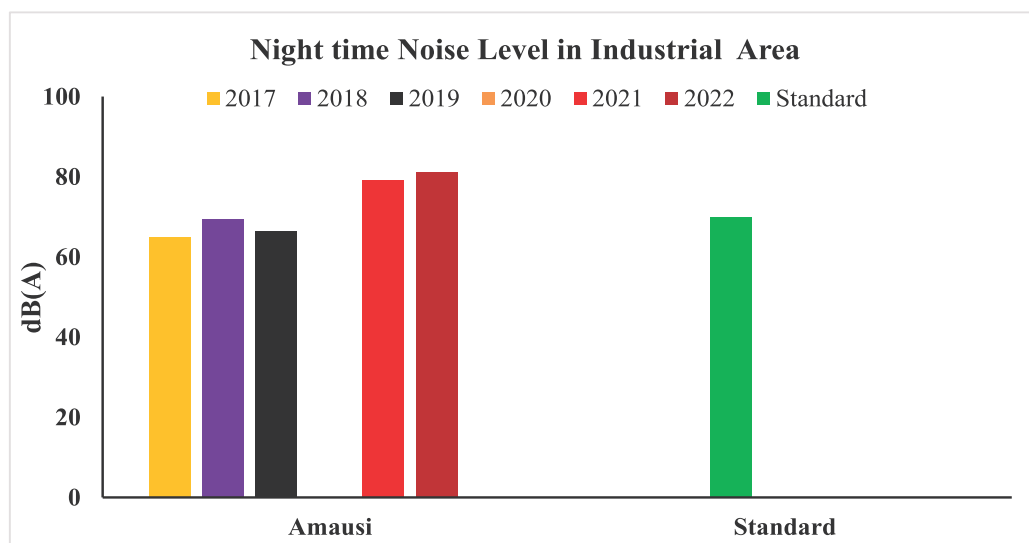
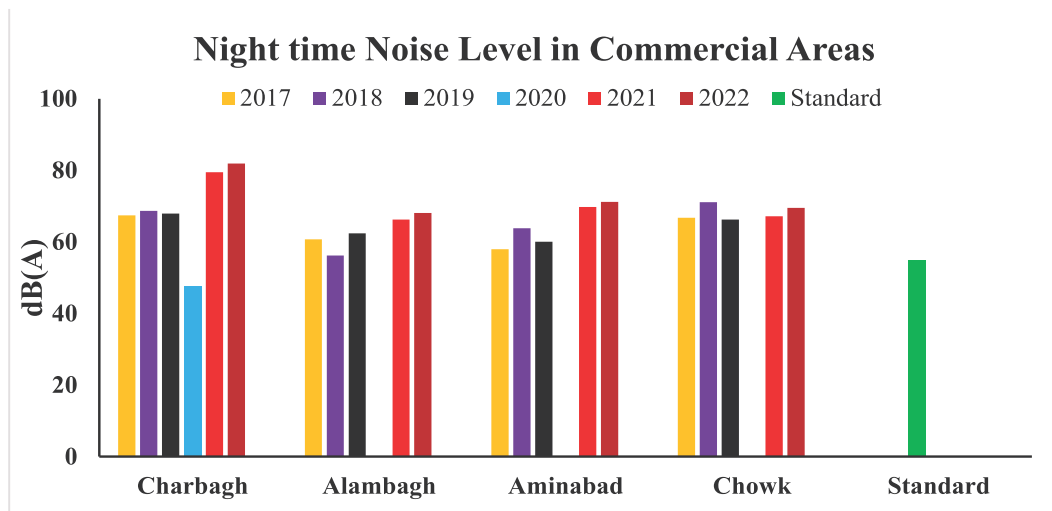
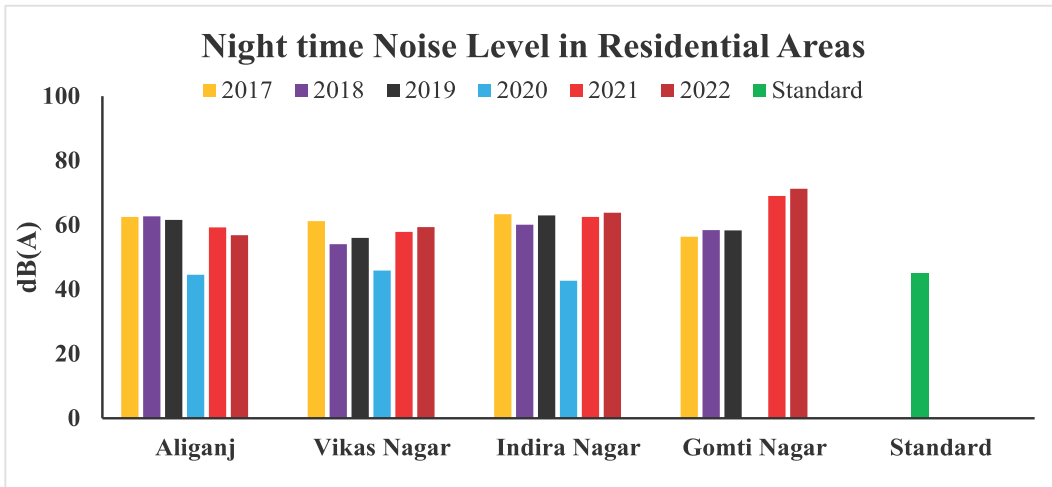


Figure 10: Comparison of night time Noise Level in dB(A) for different areas of Lucknow city (Post-monsoon 2017-2022)

1.6 CONCLUSIONS / MAIN FINDINGS

CSIR-IITR has monitored air pollutants such as PM₁₀, PM_{2.5}, SO₂, and NO₂ at 9 locations for the assessment of ambient air quality during the last week of October 2022. Besides, day and night time noise levels were also monitored at the same locations. The main findings of the study are as follows:

Vehicles

- As on 31st March 2022, the RTO registered vehicles all types in Lucknow city are 2650286 (2021-22) i.e. increased by 5.4% (increase 135825 vehicles) with compared to last year registered vehicle 2514461 (2020-21).
- The CNG vehicles of all types increased from 36017 (2020-21) to 42567 (2021-22) by 18.18% (6550 vehicles).

Fuel Consumption

- The petrol consumption for the year 2021-22 (207417.5 kL) increased by 8.51% when compared to last year petrol consumption i.e 191149.0 kL; however, diesel consumption of 157220 kL (2021-22) decreased by -11% (decrease in kL 19440). when compared to last year consumption of 176660 kL (2020-21). The CNG consumption for the year 2021-22 was 69295471 kg i.e. 158 % (increase in kg 42434821) with compared to last year CNG consumption 26860650 kg (2020-21).

Particulates and Gases

- The Post-Monsoon, 2022 PM₁₀ concentration has increased by 20.5% with compared to last year Post-Monsoon 2021 PM₁₀ data while the PM_{2.5} concentration has increased by 56.7% with compared to last year Post-Monsoon 2021 PM_{2.5} data.
- The average level of PM₁₀ (203.1 µg/m³) and PM_{2.5} (131.8 µg/m³) at all the monitoring locations of residential, commercial and industrial areas were higher than their respective NAAQS of 100 µg/m³ for PM₁₀ and 60 µg/m³ for PM_{2.5}. The average concentration of PM₁₀ has exceeded by 103.1% with respect to its

standard value ($100 \mu\text{g}/\text{m}^3$) while average concentration of $\text{PM}_{2.5}$ by 119.7 % with respect to its standard value ($60 \mu\text{g}/\text{m}^3$).

- The concentration of gaseous pollutants, SO_2 and NO_2 were below the prescribed NAAQS ($80 \mu\text{g}/\text{m}^3$) at all the locations. The average values of SO_2 have increased by 48.6 % and NO_2 has decreased by 21.4 % respectively as compared to Post Monsoon 2021 data.

Noise

- The day and night time noise levels at residential, commercial and industrial areas for the present year 2022 have exceeded by about 5.8 % ,3.0 % & 5.8% during day times and 6.3%, 2.8% & 2.6 % during night times respectively in comparison with Post Monsoon 2021.

Overall particle pollution levels during Post-monsoon 2022 were observed exceeding than the previous year Post-monsoon. The ascension of PM levels in the city due to the monitoring of Post-monsoon 2022 was conducted in the beginning of winter season and during post-Diwali days (Chaat -puja days) with accelerated city transport activities in the city. Further, crop-residue combustion at near villages to the city was also started from the third week of October 2022. Therefore, not only the sudden raise of traffic emissions but also the sulphates and nitrates compounds from Diwali-fire-crackers and crop-residue emission during prevailed calm-wind meteorological conditions of early winter days resulted to accelerate the formation and adding additional load of particulate matter to city atmosphere. Since, Lucknow is a rapidly growing city, efforts required to decelerate the rising trend of pollution. It would be an achievement even air pollution increasing rate is slowed down with progress of time. To resolve the serious air pollution issue, not only rely on comprehensive source apportionment studies but also required technology development to purify the ambient air pollution level for better air quality of the city.

1.7 RECOMMENDATIONS FOR MITIGATION OF AIR POLLUTION

1. Geographic distribution of local sources particularly open cooking combustion and construction/demolition activities in Lucknow has seasonal variability. Survey, observation and control of sources should be practiced and regularized.
2. Some haphazard developments are observed in the city area and it is recommended that all developments should be as per the norms of LDA / Nagar Nigam instructions.
3. Air pollution assessment studies should be improved with uniform design, analysis and evaluation methods for regulating and abating pollution levels.
4. Vehicular emission and resuspension of road dust are the main source of air pollution other than industries. Therefore □avoidshift-improve□ policy should be implemented (i.e., avoiding excess flow of vehicle run, shifting to modes of transport and improvement of technologies of vehicles).
5. Phase-out of old vehicles and strict control on road encroachment.
6. More and more roadside plantation / vegetation barriers to be encouraged for potential mitigation strategy for near-road air pollution.
7. Air purification device-based technologies need to be promoted to dilute the polluted air particularly at traffic junctions and busy market regions.
8. BEE-rated diesel generators should be promoted in city as these are more efficient and less polluting. Further, emissions standards for diesel generator sets shall be tightened.
9. Enforcement of improved infrastructure for collection and composting of vegetative waste and overall waste management to avoid trash burning at local areas of city.
10. Encourage green roof technologies in the city to reduce local outdoor temperatures and improve the appropriate cooling inside buildings.
11. Citizen should be made aware for behavioral actions to reduce energy consumption and emissions deriving from home heating such shift for electric cooking or PNG.
12. Photocatalytic paints should be promoted to avoid VOCs based pollutants.
13. Pollution related workshops and social education programmes should be organized for public/drivers and print media should promote clean and green environment
14. Unnecessary use of horn should be strictly avoided.
15. Low Sulphur diesel fuel / more CNG supply to be ensured in the city area.
16. State government should promote CNG/E-vehicles for newer vehicles.



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Mr. Manoj Sharma, Assistant Regional Manager, Dr. Sunil Upadhyay Senior Station Incharge, City Transport Services Ltd, Dubagga Depot, Lucknow,

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We also express our sincere thanks and gratitude to those who provided necessary facilities and support to our field team at different monitoring localities.

ANNEXURE-I

Phase-I study during Diwali, 2022

Ambient Air Quality During Pre-Diwali, Diwali and Post-Diwali Festival

October 2022



Environmental Monitoring Division

Environnement Toxicology Group

पर्यावरण अनुवीक्षण प्रभाग

पर्यावरण विषविज्ञान समूह



सीएसआईआर-भारतीय विषविज्ञान अनुसंधान संस्थान
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Ambient Air Quality during Pre-Diwali, Diwali and Post-Diwali, 2022

1.1 Introduction

Traditionally Diwali or Deepawali is known as the ‘festival of illuminations’ and occurs between post-monsoon season in India. The celebration of Diwali held for five days long begins from Dhanteras and ends on Bhaidooj with the reasons of traditional and mythological grounds. Spectacular lights, firecrackers, exchange of sweets and gifts mark this festival as special. The markets become huge rush and roads filled-in by heavy traffic due to public additional purchases starts from few days before the Diwali festival. During Diwali in every hour burning of large quantity of firecrackers occurs at surface level that fill the atmosphere with additional air pollution. The firecrackers release near ground a variety of pollutants into the lower atmosphere such as fine particles, polyaromatic hydrocarbons (PAHs), carbon monoxide, Sulphur dioxide, oxides of nitrogen, carbon dioxide, barium nitrate; metals like lithium, aluminum, copper, zinc, lead, nickel, manganese, magnesium, cadmium, and many others chemical compounds toxic to human.

Diwali festival also marks the beginning of winter season with decreases in night time temperature due to cold weather (low temperature and high humidity) and calm wind (low wind speed < 0.5 m/s) conditions. Therefore, pollution does not disperse easily and the pollutants accumulate near the ground level/ breathing. Further, during the night hours, pollutants absorb air moisture and condense others particles to increase its density and therefore, reduces its buoyancy and gradually pollutants settle down over the night. Whenever, any firecracker bursts in the air, it leads to increase of inhalable particulates and gases in to breathing zone.

In view of above, Air Quality Survey in Lucknow city during Diwali days (i.e., pre-Diwali days, on-Diwali day and post-Diwali days) has been carried out by CSIR-Indian Institute of Toxicology Research (CSIR-IITR) from past many years to find out the air and noise pollution status at different locations in the city. For Diwali 2022, particulate & gaseous pollutants and noise level monitoring is conducted at four sites

covering residential, commercial and industrial areas (i.e., Aliganj, Gomtinagar, Charbagh, and Amausi) in Lucknow to ascertain the impact of firecrackers bursting and other activities during Diwali festival, 2022 on ambient air quality in the city.

1.2 Objectives of the study

Ambient air and noise quality survey for Lucknow city was monitored during Diwali period, 2022 with the following objectives:

- *to measure the ambient concentrations of particulates (PM_{10} & $PM_{2.5}$), gases (SO_2 & NO_2) pollutants and noise levels for day and night time*
- *to examine the status & trend of air quality over the years, and develop the air quality database for Diwali period*
- *to increase the public awareness about the spike of air pollution during Diwali due to bursting of firecrackers and other festival activities*

1.3 Results and Discussion

1.3.1 Ambient air quality

Air quality analysis results for 4-monitoring sites in Lucknow are delineated in **Table-1** and **Figure-1** to **Figure-3** respectively.

The study reveals that the fine particulate matters ($PM_{2.5}$ and PM_{10}) monitored during pre-Diwali, Diwali and post-Diwali days are exceeded the National Ambient Air Quality Standards of 60 and $100\mu\text{g}/\text{m}^3$ respectively at all sampling locations (Table-1).

PM_{10} Concentration during nights of Pre-Diwali, Diwali, Post-Diwali:

Pre-Diwali day (October 23, 2022), the 12hr mean concentration of PM_{10} ranged 157 to $215\mu\text{g}/\text{m}^3$ and average $190\mu\text{g}/\text{m}^3$ during night time (6PM to 6AM).

On Diwali (October 24, 2022), the 12hr mean concentration of PM_{10} ranged 275 to $509\mu\text{g}/\text{m}^3$ and average $396\mu\text{g}/\text{m}^3$ during night time (6PM to 6AM).

During Post-Diwali (October 25, 2022), the 12hr mean concentration of PM_{10} ranged 198 to $412\mu\text{g}/\text{m}^3$ and average $316\mu\text{g}/\text{m}^3$ during night time (6PM to 6AM).

$PM_{2.5}$ Concentration during nights of Pre-Diwali, Diwali, Post-Diwali:

Pre-Diwali day (October 23, 2022), the 12hr mean concentration of $PM_{2.5}$ ranged 82 to $138\mu\text{g}/\text{m}^3$ and average $107\mu\text{g}/\text{m}^3$ during night time (6PM to 6AM).

On Diwali (October 24, 2022), the 12hr mean concentration of $PM_{2.5}$ ranged 194 to $386\mu\text{g}/\text{m}^3$ and average $279\mu\text{g}/\text{m}^3$ during night time (6PM to 6AM).

During Post-Diwali (October 25, 2022), the 12hr mean concentration of $PM_{2.5}$ ranged 117 to $295\mu\text{g}/\text{m}^3$ and average $204\mu\text{g}/\text{m}^3$ during night time (6PM to 6AM).

On Diwali night, the average level of PM_{10} had increased 108.8 % from the pre-Diwali night and reduced by 20.2% in post-Diwali night.

On Diwali night, the average level of $PM_{2.5}$ had increased 162.2 % from the pre-Diwali night and reduced by 27.0% in post-Diwali night.

In case of SO_2 and NO_2 , the mean level was found to be within prescribed limits. However, maximum level of SO_2 and NO_2 on the Diwali night was observed as $40.5\mu\text{g}/\text{m}^3$ and $54.0\mu\text{g}/\text{m}^3$ respectively at Charbagh location.

Meteorology for Lucknow city has been extracted from CPCB and found the prevailing wind conditions (wind-speed and wind-direction) of the city during Diwali, 2022 is presented in **Figure-4**. Mean temperature and relative humidity is observed during Diwali 2022 as 20.8°C and 66.5 % respectively.

Table 1. Air Pollution Levels during Diwali 2022 in Lucknow

Locations	Pre-Diwali 2022 (October 23, 2022)	On-Diwali 2022 (October 24, 2022)		Post-Diwali 2022 (October 25, 2022)	
	Night (6:00 pm to 6:00 am)	Day (6:00 am to 6:00 pm)	Night (6:00 pm to 6:00 am)	Day (6:00 am to 6:00 pm)	Night (6:00 pm to 6:00 am)
Pollutant : PM₁₀ (µg/m³)					
Aliganj	207	278	415	247	369
Gomti Nagar	179	269	384	200	285
Charbagh	215	331	509	268	412
Amausi	157	184	275	149	198
Average	190	265	396	216	316
Pollutant : PM_{2.5} (µg/m³)					
Aliganj	113	198	295	137	205
Gomti Nagar	93	169	242	139	198
Charbagh	138	251	386	192	295
Amausi	82	130	194	88	117
Average	107	187	279	139	204
Pollutant : SO₂ (µg/m³)					
Aliganj	22.0	24.1	36.0	16.1	24.0
Gomti Nagar	20.0	23.8	34.0	16.1	23.0
Charbagh	28.2	26.3	40.5	21.0	32.3
Amausi	15.0	20.8	31.0	13.5	18.0
Average	21.3	23.8	35.4	16.7	24.3
Pollutant : NO₂ (µg/m³)					
Aliganj	29.0	28.8	43.0	24.1	36.0
Gomti Nagar	28.0	28.0	40.0	22.4	32.0
Charbagh	33.0	35.1	54.0	27.3	42.0
Amausi	21.0	23.5	35.0	18.8	25.0
Average	27.8	28.8	43.0	23.1	33.8

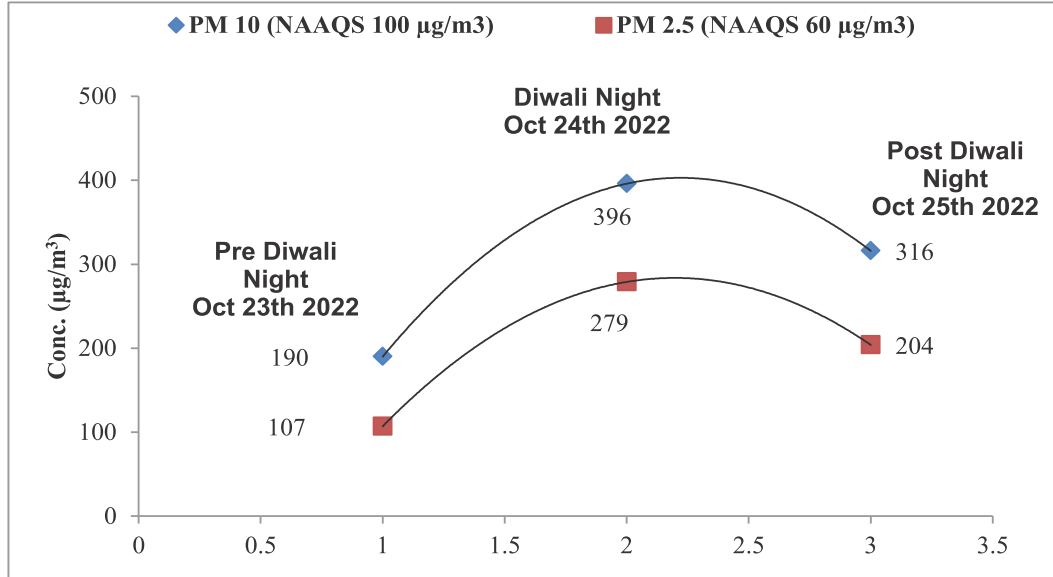


Figure-1. Profile of fine particulate matters (PM_{2.5} and PM₁₀) during the night time of Diwali Festival, 2022.

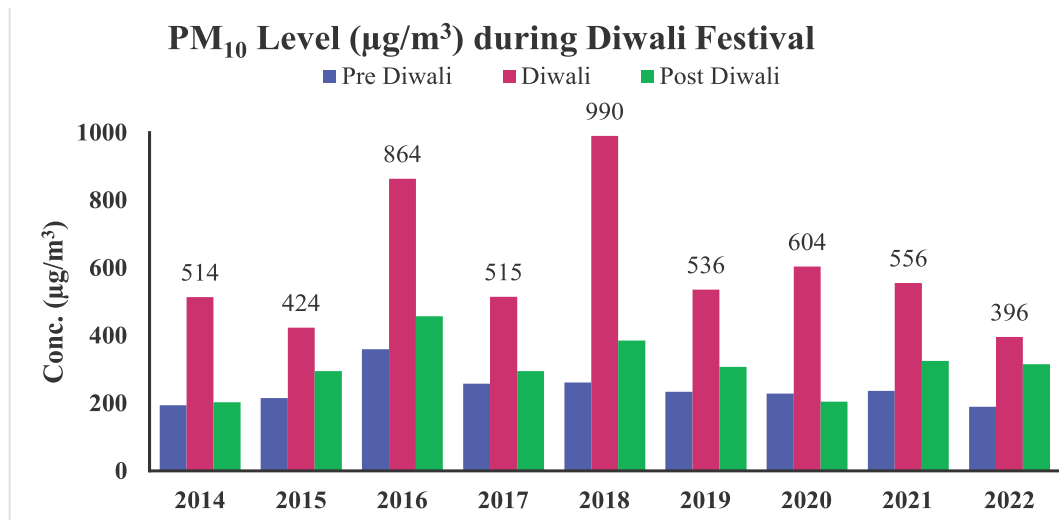


Figure-2. Trend of respirable particulates (PM₁₀) concentration during 2014, 2015, 2016, 2017, 2018 2019, 2020, 2021 and 2022 (Night time Diwali Festival)

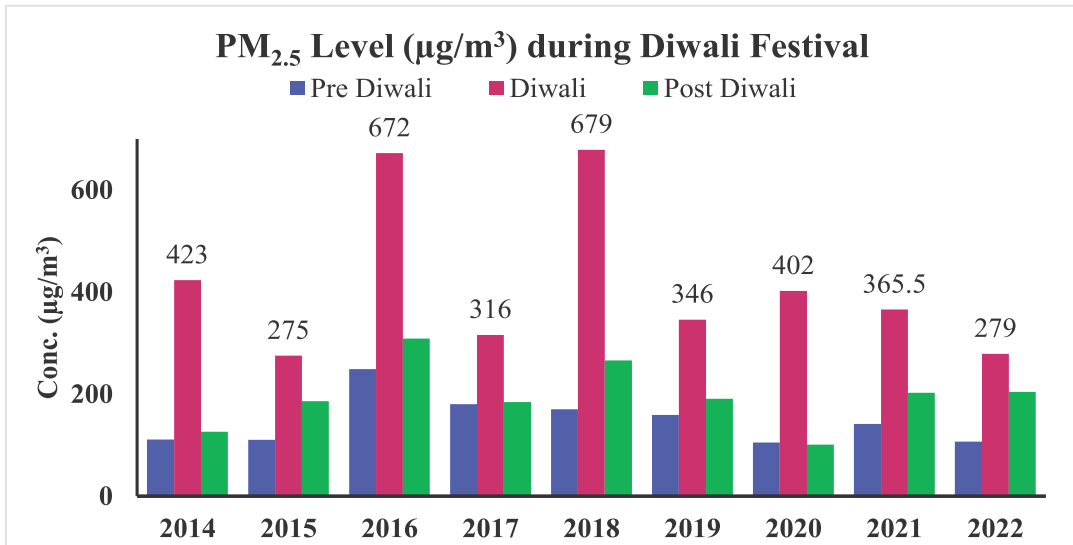


Figure-3. Trend of fine particulates (PM_{2.5}) concentration during 2014, 2015, 2016, 2017, 2018 2019, 2020, 2021 and 2022 (Night time Diwali Festival)

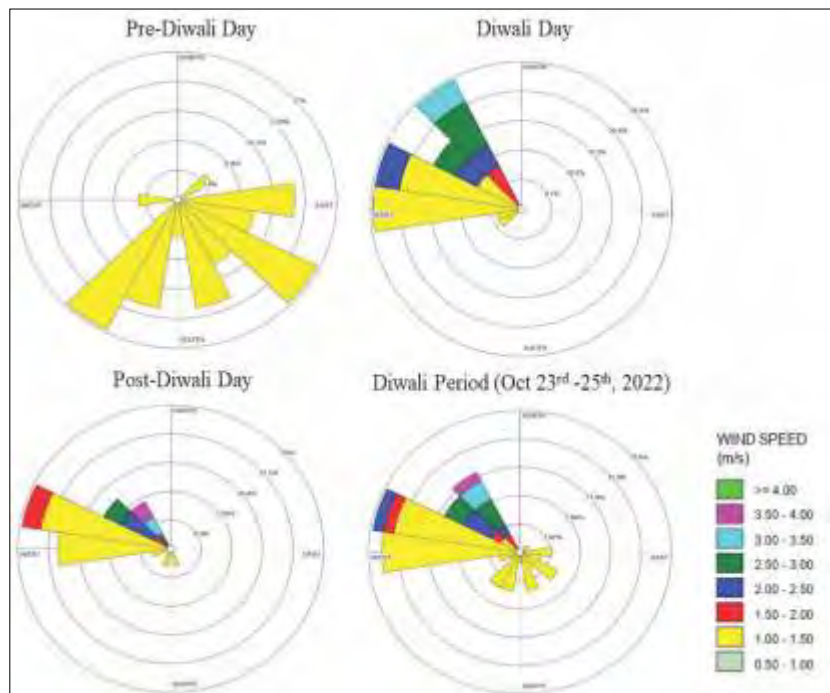


Figure-4: Wind-speed and wind-direction in Lucknow city during Diwali, 2022

1.3.2 Noise level

The noise levels were measured at 4 locations during Pre-Diwali, Post-Diwali and On-Diwali night to assess the impact of bursting of firecracker as well as other activities (Table-2). The noise levels were monitored during nights between 7PM – 1AM for ~20 minutes at each location.

The highest noise level was recorded at Charbagh area on Diwali night with 80.6 dB(A) whereas the lowest was recorded at Aliganj with 66.3 dB(A) on pre-Diwali night. Firecrackers with noise level > 80dB(A), may damage eardrum and reduce our hearing ability. High noise can may induce temporary or permanent hearing impairment.

Table 2. Noise Level in dB(A) on Pre-Diwali, Diwali and Post-Diwali

Locations	Pre-Diwali (October 23, 2022)	On-Diwali (October 24, 2022)	Post- Diwali (October 25, 2022)
Charbagh (10:00-10:30 PM)	72.8	80.6	78.1
Aliganj (10:00-10:30 PM)	66.3	75.8	68.5
Gomti Nagar (10:00-10:30 PM)	79.4	80.4	71.6
Amausi (10:00-10:30 PM)	81	69.8	71.1



1.4 Conclusion

Ambient air and noise quality survey results for Lucknow city during Diwali 2022 revealed that the particulate and gaseous pollution levels found drastically exceeded from pre-Diwali to Diwali and again found slightly decreased to post-Diwali day. The results of survey during Diwali festival, 2022 clearly indicated the significant deterioration of air quality in Lucknow city. Also, in-comparison with previous Diwali festivals (i.e., during Diwali-2021 and 2020), current festival study results identified decreased pollution levels because this year Diwali was celebrated in early winter season with better meteorological conditions for air pollution dispersion. The large quantity of pollutants and noise levels formed due to burning of firecrackers and other festival activities during Diwali 2022 which may the cause to increased mortality and morbidity in urban area. Individual bursting of firecrackers during Diwali should be discouraged. However, alternatively community celebration may be allowed at predefined areas.



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