Assessment of Ambient Air Quality of Lucknow City

Post Monsoon 2024

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सीएसआईआर-भारतीय विषविज्ञान अनुसंधान संस्थान

CSIR-INDIAN INSTITUTE OF TOXICOLOGY RESEARCH

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Salient Features of the Study Area: Lucknow

- **Geographical Position** : 26° 52' N Latitude
  80° 56' E Longitude
  128 m above Sea Level
- **Area** : 631 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. The average annual rainfall is about 100 cm.
- **Total Vehicular number as on 31/03/2024** : 2979734
- **Growth of Vehicles over 2023-2024** : 5.8%
- **Total No. of Fuel Filling Stations (Petrol/Diesel/CNG)** : 173
- **Consumption of Fuel**
  - **Petrol** : 262122 kL
  - **Diesel** : 173442 kL
  - **CNG** : 52566780.15 kg
- **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, Pb, Ni, and Noise Level
- **Study Conducted by** : Environmental Monitoring Laboratory
  CSIR-IITR, Lucknow

ASSESSMENT OF AMBIENT AIR QUALITY OF LUCKNOW CITY DURING POST-MONSOON, 2024

Executive Summary

The air quality survey has been conducted by the institute for parameters of PM_{10}, $PM_{2.5}$, SO_2, NO_2, Lead (Pb), Nickel (Ni), and Noise levels of day-time and night-time at 9 monitoring sites covering representative residential, commercial, and industrial areas in the Lucknow city during September and October 2024 (i.e., post-monsoon 2024).

Maximum concentrations for particulate matter have exceeded their NAAQS limits at all the monitoring sites in the city (i.e., 100 $\mu g/m^3$ for PM_{10} and 60 $\mu g/m^3$ for $PM_{2.5}$). Overall in the city, the average concentration exceedance was up to 0.31 times in PM_{10} and 0.41 times in $PM_{2.5}$ than their national limits. However, gaseous pollutants (i.e., SO_2 and NO_2) were within their national limits of 80 $\mu g/m^3$. Further, the associated toxic metals with PM_{10} (i.e., Pb and Ni) were also found within their ambient standards. Whereas, the record of Noise levels during day-time and night-time were identified exceeded the respective national noise limits.

The post-monsoon air quality survey results were significantly influenced by the rains of monitoring days. There is a decreased concentration level of particle pollution in the city was observed in comparison with the pre-monsoon 2024. The monsoon rains scavenge the particles in the atmosphere and the wet surface controls dust from its resuspension to ambient air. During the post-monsoon, the increased atmospheric humidity can lead to the agglomeration of particles which makes the particles heavier and deposited on the ground from the atmosphere. The activities in the city like construction, markets, and movement of vehicles are also reduced due to the effect of rains. However, the yearly increment of registered vehicular numbers and fuel consumption in the city has a likely impact on slightly exceeded air pollution concentration than their national standards.

In spite of the natural impact of rain in the city, multiple action plans have also been implemented in the city to mitigate the ambient air pollution concentration. The plantation has been enhanced between the city roads, which control the dispersion of vehicular emissions and road dust. The public transport of the city has been shifted to cleaner fuels with EV buses (by 146 number) and CNG buses (by 55 number) for plying on city roads. Besides the other E-vehicles have increased by 51 % from the previous year 2023. There is also an increase in the number of passengers traveling in Lucknow metro. The completion of the ongoing construction activities such as outer ring roads, flyovers, and connecting roads will also help to reduce the traffic influence on air pollution in the city.

Air pollution is a changing phenomenon with respect to location and time due to fluctuating natural and man-made activities. Continuous awareness of the status of city air quality, and efforts by the individual and government communities are essential for the safe-guard of public health.

1.0 Introduction

Atmosphere air in its natural form is a mix of gases mainly 78.0% Nitrogen and 20.9% Oxygen. It also has other compounds in very small quantities such as CO_2 (0.04%), SO_2 (0.0002%), NO_2 (0.0001%), NO (0.0002%), CO (0.0001%) and moisture (4%). Air pollutants in various forms, such as solid, liquid, or gaseous enter into the atmosphere by diverse processes, and each one has unique properties to complexity in nature. Therefore, the atmospheric air includes typical pollution compounds like ozone (O_3), particulate matter (PM), carbon dioxide (CO_2), Sulfur dioxide (SO_2), Nitrogen dioxides (NO_2), and volatile organic compounds (VOCs), etc. With industrialization and urbanization, human activities have increased and the level of particulate matter and various gases is continuously increasing in the atmosphere. Thus, the increase in the natural levels of particulate matter and various gases in the atmosphere resulted in air pollution. These contaminants are changing the natural characteristics of the atmosphere through aerosolized physico-chemical and biological agents. Air pollution is a global phenomenon, a result of economic growth, and fulfills the needs of the public. Exposure to harmful air pollutants harms human and plant health as well as on buildings. Common sources that enhance air pollution in the urban atmosphere are road transportation, wind-blown dust, construction/demolition emissions, industrial emissions, market/ restaurant/ bakery, and residential cooking combustions, and open waste dumps and their burning, etc. Besides, land-use patterns of the city, its ground elevation, and local meteorology also have a significant impact on the fluctuations of air quality levels.

Under the NAMP (National Air Monitoring Programme) network, ground-level ambient air pollution monitoring has been carried out for more than three decades by State and Central Pollution Control Boards at 804 stations across 344 cities and towns in 28 states and 6 Union Territories. Based on NAMP data, CPCB has identified spatial hot spots (highly polluted cities). Most of the urban locations in the country have been included under the list of hot spot sites. CPCB has identified 131 cities in 24 states, that do not meet the NAAQS (National Ambient Air Quality Standard) in consistent years and declared them as ‘non-attainment’ cities of India. Thus, the MoEF&CC (Ministry

of Environmental Forest and Climate Change) and CPCB have formulated NCAP (National Clean Air Programme) by including the local expertise as IoR (Institute of Reputes) in each city for scientific investigations and source apportionment study-based city-specific action plan preparation.

The seasonal and different function zones-based status of air pollution in any city significantly supports the regulators to prepare effective actional plans for control/ mitigation of atmospheric pollution load. In this connection, CSIR-Indian Institute of Toxicology Research, one of the IoRs under NCAP of MoEF&CC, is also conducting air pollution monitoring and assessment in Lucknow city regularly to address the influence of seasonal variations and land use changes under different functional zones on air quality.

1.1 Layout of Lucknow City

Lucknow is the capital and the largest city of the Indian state of Uttar Pradesh and the city's area and urban population are growing at a very rapid pace. The present population is anticipated to touch 35 lakhs. Lucknow is the eleventh-most populous city and the twelfth-most populous urban agglomeration of India. Bounded on the east by Barabanki, on the west by Unnao, on the south by Raebareli , and on the north by Sitapur and Hardoi, Lucknow sits on the northwestern shore of the Gomati. Gomati River flows across the city and divides it into 2 parts viz Cis and Trans Gomati. The city stands at an elevation of 124 meters (404 ft) above sea level. Lucknow city had an area of 402 km^2 till December 2019, when 88 villages were added to the municipal limits, and the area increased to 631 km^2. Lucknow has always been a multicultural city that flourished as a North Indian cultural and artistic hub and the seat of power of Nawabs in the 18th and 19th centuries. It is an important center of governance, administration, education, commerce, aerospace, finance, pharmaceuticals, technology, design, culture, tourism, music and poetry.

1.2 Vehicular Inventory and Fuel Consumption in the City

Registered vehicles inventory of Lucknow city and other primary information were collected from RTO (Regional Transport Office) as of March 31, 2024 (Table 1). Based on vehicular inventory, an increase in registered vehicle numbers is observed by 5.8 % in the city from last year 2022-23. The total number of CNG & electrical buses of UPSRTC operational is 55 & 146 respectively by 2024 (Table 2 & 3). City has also recorded continuous growth in the number of E-Vehicles over the years. Different oil and gas companies have provided the total number of fuel outlets (i.e. petrol, diesel & CNG) in Lucknow are 173 (Table 4). Consumption of fuel between years 2023 and 2024 is presented in Table 5, and it is found that the consumption of petrol, diesel, CNG and LPG decreased by 0.2%, 14.3%, 24.8%, and 21.9% by 2023-24. The number of registered CNG and E-vehicles and their growth from the previous year in the city are reported in Table 6(a) and Table 6(b).

1.3 Study rationale

Lucknow is one of the non-attainment cities identified in NCAP of MoEF&CC as the levels of air pollutants violated the prescribed NAAQS 2009. Further, source apportionment studies of the city also reported that there is a significant increase in ambient air pollution concentration in Lucknow. To better understand atmospheric chemistry, air quality, and its impact on human health, spatially and temporally distributed air pollution levels in the city are required to be known. This is also especially important for the policy-makers to formulate effective emission control strategies and air quality management plans for clean air in the city.

Dominant sources for the poor air quality of the city are traffic emissions, construction/demolition activities (buildings, flyovers, elevated roads, and new roads) waste burning, cooking fuel combustion, road dust entrainment, etc. Despite air pollution abatement measures in the city, and the enforcement of BS-VI compliance vehicles, CNG, and e-vehicles on national wide, air pollution reduction in the city still breaching their national standards and it has become a great challenge for policymakers.

Installation of proper traffic signals to control vehicle movements has also been taken up by the authorities. However, the idle mode of vehicles, as well as traffic jams at multiple signals, has affected the air quality. Further, the increase in urban population and economic activities has resulted in demands for open cooking and street food stall activities, which in turn has increased the cooking combustion-related emission load to ambient air. The problem is often compounded by the predominance of widely distributed area (fugitive) sources in the city, and also the lack of understanding of the sources of secondary aerosol, their formation, and transport.

The city has witnessed an extended rainy season during the current air quality survey conducted by the institute. During this period, the ongoing construction activities have been observed to be interrupted. However, commercial and transport activities including the resuspension of dust and domestic cooking activities are the major sources of atmospheric pollution in the city. Also, the initiatives like cleaning programmes under the Swachha Bharat Programs by the State Govt. have taken. However, many off-site localities/ areas of the city have huge garbage and waste dumps contributing to air pollution.

Therefore, the current status of air pollution in the city is important to know for regulating the sources and receptor linkages and implementing cost-effective abatement measures to reduce air pollution load in the city. To address the air pollution status of Lucknow city, CSIR-IITR has been conducting air quality surveys at 9 locations across Lucknow city since 1997 for the pre-monsoon (May-June) and post-monsoon (September-October) seasons every year. The regular air quality survey identifies the new sources, vehicular and fuel consumption inventory in the city, and generates air pollution data of different functional zones and seasons of the city for public awareness and to support government agencies in enforcing the control measures. On account of these understandings, this report complies with the study results of post-monsoon 2024 (September to October) air quality survey at 9 locations in Lucknow city covering industrial, residential, and commercial areas with respect to PM_{10}, $PM_{2.5}$ SO_2, NO_2, trace metals (Pb and Ni), and Noise pollution. Further, this report illustrates the scientific

discussion, interpretations, and recommendations for the reduction of air pollution load in the city.

1.4 Objectives

The following objectives are delineated for the Post-monsoon 2024 study:

- *To study the air quality status of post-monsoon season of 2024 at different functional areas of the city*
- *To ascertain the concentration of PM_{10}, $PM_{2.5}$, SO_2, NO_2, and trace metals (Pb and Ni) associated with PM_{10}.*
- *To study the trend of air pollution in Lucknow city over the years.*
- *To find out the day and night-time Noise levels of the current season at different functional areas of the city*
- *To provide awareness on the current air pollution status of the city*
- *To develop the scientific database and recommendations to assist regulatory agencies for remedial measures in the city*

Table 1: Comparison of Vehicle Numbers in Lucknow

S. No.	Type of Vehicles	Number of Registered Vehicles as on 31st March		Increment in %
		2023-24	**2022-23**	
1	Multi Articulated	8233	7879	4.5
2	Light, Medium & Heavy Weight Vehicles (Four Wheelers)	63060	61273	2.9
3	Light Commercial Vehicles (Three Wheeler)	4685	4074	15.0
4	Buses	5362	5076	5.6
5	Omni Buses	553	551	0.4
6	Taxi	64569	63648	1.4
7	Light Motor Vehicles (Passenger)	22426	11250	99.3
8	Two Wheelers	2098522	2012795	4.3
9	Car	599023	544698	10.0
10	Tractors	32783	30899	6.1
11	Trailers	2307	2174	6.1
12	Others	78211	71976	8.7
Increase in total number of vehicles		**2979734**	**2816293**	**5.8**

Source: *RTO Lucknow, 2024*

Table 2: Details of CNG City Bus Service (Gomati Nagar Depot, 2024) in Lucknow

S. No.	Route No.	To and Fro	No. of Buses	Frequency (minutes)
1	101	Goyal instutute to Charbagh via Patrakaar Puram and Parivartan Park	08	11
2	202	Industrial area Scooter India to Gomatinagar high court via Ramabai maidaan and Utretia	27	04
3	402	Integral university to Rajnikhand Nishatganj via GPO and Charbagh	20	06
Total			**55**	

Table 3: Details of Electric City Bus Service (Dubagga Depot, 2024) in Lucknow

S.No.	Route No.	To and Fro	No. of Buses
1	PMI-01	Dubagga to Baddu Pur via Parivartan	03
3	PMI-02	Dubagga to Gangaganj via Charbagh and Gosainganj	08
4	PMI-03	SGPGI to Bhawani Khera via Charbagh and Atal Chowk	04
6	PMI-05	Ghantaghar to Sandila via Chowk and Dubagga	12
7	PMI-06	Balaganj Chauraha to Gudwa Chauraha via Maal	07
8	PMI-07	Rajajipuram bus terminus to Dewa via Charbagh and Polytechnic	14
10	PMI-08	Scooter India to Engineering college via Charbagh and Kapoorthala	04
11	PMI-10	Ghanta Ghar to Bauniganj via Balaganj and Dubagga	02
12	PMI-11	Ghanta Ghar to Nabeenah via Andhi ki chawki	05
13	PMI-13	Charbagh to Chandrika Devi Mandir via Engg College	01
14	801E	Balaganj to Viraj Khand via Polytechnic	14
15	1201E	Dubagga to Bindhaua via Sitapur Bypass and SGPGI	20
16	105	Rajajipuram to BBD via Charbagh and Chinhat	08
17	301	Scooter India to Engg. College via Awadh Hospital and Charbagh	12
18	502 (B)	Scooter India to Kamta via Utrathia and Ekana Stadium	14
19	801	Balaganj to Viraj Khand via Dubagga	12
	801 D	Pradhanmantri awas to Awadh bus stand via Parivartan park	02
20	902	Kamta to Polytechnique via Charbagh	02
21	1001	Ghanta Ghar to Naimisharanya via Sandila	02
Total			**146**

Table 4: Fuel Outlets in Lucknow City

S.No.	Agency	Number of outlets as of 31st March 2024
1	Indian Oil Corporation Limited (IOCL)	62
2	Bharat Petroleum Corporation Limited (BPCL)	34
3	Hindustan Petroleum Corporation Limited (HPCL)	35
4	Compressed Natural Gas Stations (CNGS)	40
5	Liquefied Petroleum Gas Stations (LPGS)	2
Total		**173**

Table 5: Fuel Consumption in Lucknow City, 2024

S. No.	Agency	Petrol in kL			High-Speed Diesel in kL			CNG in kg		
		Apr. 23 to Mar. 24	Apr. 22 to Mar. 23	% Change	Apr. 23 to Mar. 24	Apr. 22 to Mar. 23	% Change	Apr. 23 to Mar. 24	Apr. 22 to Mar. 23	% Change
1.	IOCL	135307	128699	5.1	86133	97617	-11.8	21089517.3	14786685	42.6
2.	BPCL	78017	78502	-0.6	47680	51276	-7.0	1667959.36	120000	1290.0
3.	HPCL	48798	55500	-12.1	39629	53400	-25.8	4018924.24	4018000	0.0
4.	GGL	-	-	-	-	-	-	25790379.23	51001829	-49.4
Total		**262122**	**262701**	**-0.2**	**173442**	**202293**	**-14.3**	**52566780**	**69926514**	**-24.8**
		LPG in Ton								
5.	**IOCL**	**Apr. 23 to Mar. 24**	**Apr. 22 to Mar. 23**	**% Change**	-	-	-	-	-	-
		517	662	-21.90	-	-	-	-	-	-

Source: *M/s Indian Oil Corporation Limited (IOCL), Lucknow; M/s Bharat Petroleum Corporation Limited (BPCL); M/s Hindustan Petroleum Corporation Limited (HPCL); M/s Green Gas Limited (GGL), Lucknow, 2024*

Table 6 (a): Comparison of Registered CNG Vehicles in Lucknow

S. No.	Vehicles	Number		% of Change
		2022-23	2023-24	
1	Auto Rickshaws	4343	8167	88.0
2	Tempo Taxi	2575	4424	71.8
3	Buses	302	354	17.2
4	School Buses	5520	5544	0.4
5	Private Cars	34711	41302	19.0
	Total	**47451**	**59791**	26.0

Source: *RTO Lucknow, and Green Gas Limited, Lucknow*

Table 6 (b): Comparison of Registered EV-Vehicles in Lucknow

S. No.	Vehicles	Number		% of Change
		2022-23	2023-24	
1	Buses	40	0	–
2	e-Rickshaw with Cart (G)	434	953	54
3	e-Rickshaw (P)	10277	11809	13
4	Goods Carrier	1	524	100
5	M-Cycle / Scooter	1965	8601	77
6	Moped	1	4	75
7	Motor Cab	2	7	71
8	Motor Car	169	1072	84
9	Three Wheeler (Goods)	41	451	91
10	Three Wheeler (Passenger)	778	4441	82
	Total	**13708**	**27862**	**51**

Source: *RTO Lucknow, Lucknow*

2.0 Monitoring Locations and Methodology

Nine air quality monitoring locations covering different functional areas in the city i.e., representative of 4 residential, 4 commercial cum traffic, and 1 industrial area were selected for the Post-monsoon 2024 study as summarized in Table 7 and Figure 1 and measurement methodologies are given in Table 8. A total of 6 weeks sampling was conducted during September-October, 2024.

Table 7: Monitoring Locations

S .No.	Locations	Activities
1	Aliganj	Residential
2	Vikas Nagar	Residential
3	Indira Nagar	Residential
4	Gomati 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 (as per CPCB, 2009)
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 (i.e., Pb and Ni)	24 hours	Associated with PM_{10} sample and analyzed through AAS facility of IITR
6.	Noise Level	1 hour	The measurement of noise level was carried out during the day (6 AM to 10 PM) and night time (10 PM to 6 AM) by Noise Level Meter

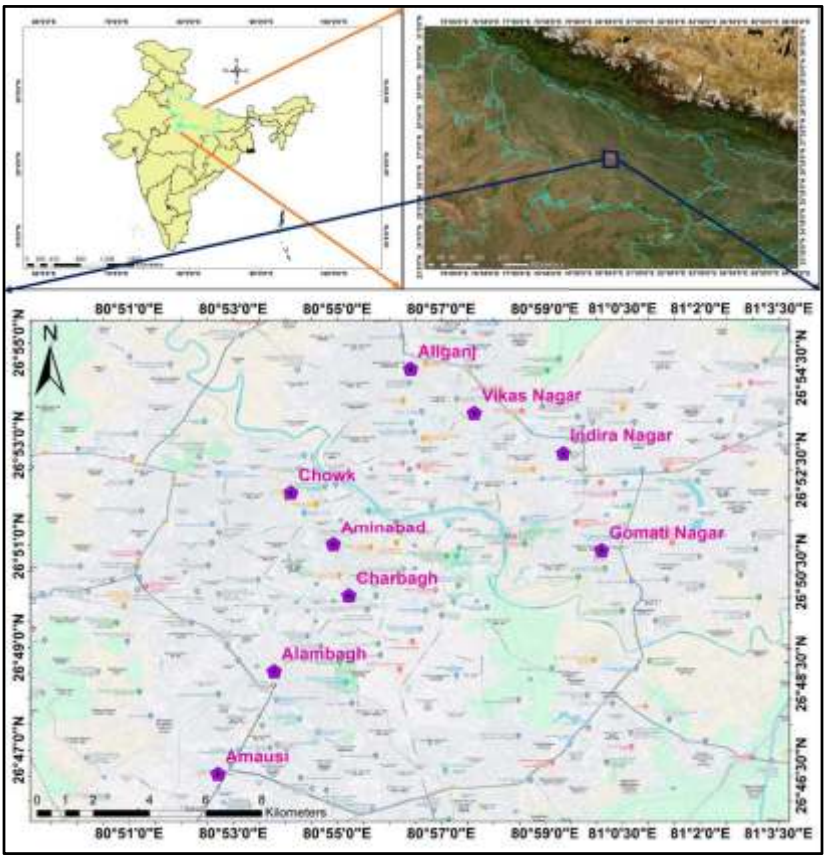


Figure 1: Ambient air pollution monitoring/sampling locations in Lucknow city

3.0 Results

The detailed results of air quality monitoring for post-monsoon 2024 are presented in Table 9, Figure 2, and Figure 3, and the following sections discuss the inferences of results.

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

In residential areas (Aliganj, Vikas Nagar, Indira Nagar and Gomati Nagar), the 24-hour concentrations of PM_{10} were in the range of 42.8 to 217.7 µg/m^3 with an average of 110.6 µg/m^3. The average concentration of PM_{10} was observed highest at Gomati Nagar among the residential areas.

In commercial areas (Charbagh, Alambagh, Aminabad and Chowk) the concentrations of PM_{10} were in the range of 64.9 to 248.3 µg/m^3 with an average of 153.2 µg/m^3 respectively. The average concentration of PM_{10} was observed highest at Charbagh among the commercial areas. In an industrial area (Amausi), the average concentration of PM_{10} was 129.4 µg/m^3.

However, in all locations, PM_{10} levels exceeded the prescribed National Ambient Air Quality Standard (NAAQS) of 100 µg/m^3.

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

In residential areas (Aliganj, Vikas Nagar, Indira Nagar and Gomati Nagar), the 24-hour concentrations of $PM_{2.5}$ were in the range of 29.5 to 139.3 µg/m^3 with an average of 69.8 µg/m^3. The average concentration of $PM_{2.5}$ was observed highest at Gomati Nagar among the residential areas.

In commercial areas (Charbagh, Alambagh, Aminabad, and Chowk) the concentration of $PM_{2.5}$ was in the range of 42.5 to 201.3 µg/m^3 with an average of 95.0 µg/m^3 respectively. The average concentration of $PM_{2.5}$ was observed highest at Charbagh among the commercial areas. In an industrial area (Amausi), the average concentration of $PM_{2.5}$ was 106.8 µg/m^3.

However, in all locations, $PM_{2.5}$ levels exceeded the prescribed National Ambient Air Quality Standard (NAAQS) of 60 µg/m^3.

3.3 Sulphur Dioxide (SO_2)

In residential areas (Aliganj, Vikas Nagar, Indira Nagar and Gomati Nagar), the levels of SO_2 were in the range of 7.3 to 23.6 µg/m^3 with an average of 12.5 µg/m^3. In commercial areas (Charbagh, Alambagh, Aminabad and Chowk) the concentrations of SO_2 were in the range of 8.7 to 29.4 µg/m^3 with an average of 21.2 µg/m^3. In an industrial area (Amausi), the mean level of SO_2 was 13.8 µg/m^3. However, all the values of SO_2 were well below the prescribed NAAQS of 80 µg/m^3 for all the locations.

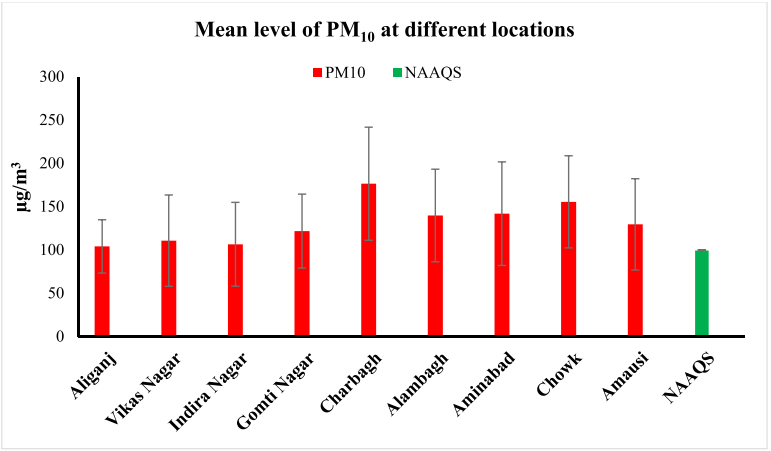
3.4 Nitrogen Dioxide (NO_2)

In residential areas (Aliganj, Vikas Nagar, Indira Nagar and Gomati Nagar) the 24-hour concentration of NO_2 was in the range of 10.2 to 40.8 µg/m^3 with an average of 23.8 µg/m^3. In commercial areas (Charbagh, Alambagh, Aminabad and Chowk) the concentration of NO_2 was in the range of 13.8 to 58.4 µg/m^3 with an average of 34.3 µg/m^3. In an industrial area (Amausi), the average concentration was 31.1 µg/m^3. However, all the values of NO_2 were within the prescribed NAAQS of 80 µg/m^3 for all the monitoring locations.

Table 9: Concentration (µg/m^3) of PM_{10}, $PM_{2.5}$, SO_2 and NO_2 during Post-monsoon 2024

Location	PM_{10} (RSPM)			$PM_{2.5}$			SO_2			NO_2		
Residential												
	Min	**Max**	**Avg.**	**Min**	**Max**	**Avg.**	**Min**	**Max**	**Avg.**	**Min**	**Max**	**Avg.**
Aliganj	56.7	170.2	103.9 ± 30.8	38.2	104.9	60.8 ± 24.9	7.3	16.4	11.5 ± 5.4	10.2	32.6	21.3 ± 12.9
Vikas Nagar	42.8	179.5	110.6 ± 52.7	29.5	103.8	72.4 ± 29.8	7.9	19.1	12.2 ± 4.5	11.5	38.4	24.9 ± 10.7
Indira Nagar	45.6	192.5	106.4 ± 48.4	32.1	69.7	64.5 ± 25.1	7.5	18.6	12.8 ± 4.8	10.7	37.9	23.4 ± 15.3
Gomati Nagar	53.1	217.7	121.6 ± 42.7	36.4	139.3	81.5 ± 30.7	8.7	23.6	13.5 ± 5.3	12.2	40.8	25.8 ± 10.2
Average	**49.6**	**190.0**	**110.6**	**34.1**	**104.4**	**69.8**	**7.9**	**19.4**	**12.5**	**11.2**	**37.4**	**23.8**
Commercial												
Charbagh	84.6	248.3	176.3± 65.3	55.7	201.3	113.6 ± 30.3	12.3	29.4	24.7 ± 8.3	18.5	58.4	37.8 ± 21.1
Alambagh	64.9	168.6	139.6 ± 53.5	42.5	110.4	76.3 ± 36.8	8.7	24.5	16.3 ± 5.9	13.8	51.4	29.5 ± 19.0
Aminabad	75.2	199.3	141.7 ± 59.8	47.8	143.6	87.8 ± 38.4	10.9	26.2	20.5 ± 6.2	16.9	54.9	33.7 ± 17.5
Chowk	79.8	213.5	155.4 ± 53.2	54.3	186.7	102.2 ± 33.6	12.1	28.9	23.6 ± 7.3	16.3	55.2	36.4 ± 18.3
Average	**76.1**	**207.4**	**153.2**	**50.1**	**160.5**	**95.0**	**11.0**	**27.3**	**21.2**	**16.4**	**55.0**	**34.3**
Industrial												
Amausi	62.5	171.6	129.4 ± 52.7	48.2	169.8	106.8 ± 31.3	10.17	16.35	13.8 ± 4.2	14.2	56.5	31.1 ± 17.2
NAAQS	100			60			80			80		
WHO Guidelines	50			25			20			40*		

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



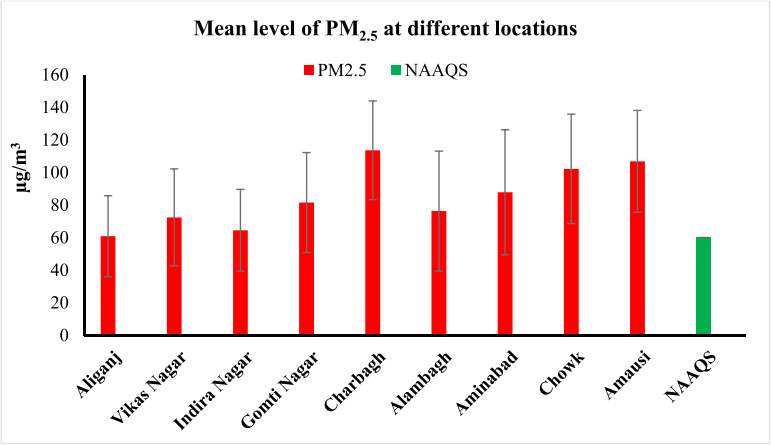


Figure 2: Concentration (µg/m^3) of PM_{10} and $PM_{2.5}$ in different functional areas of Lucknow city during post-monsoon 2024 and comparison with prescribed National Ambient Air Quality Standard (NAAQS)

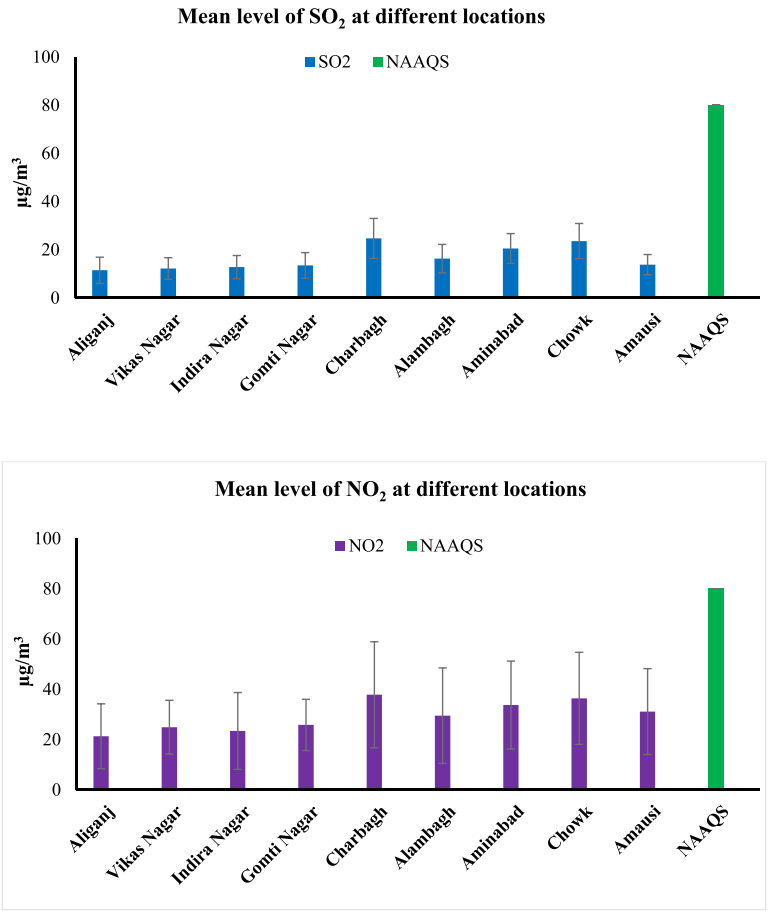


Figure 3: Concentration (µg/m^3) of SO_2 and NO_2 in different areas of Lucknow city during post-monsoon 2024 and comparison with prescribed National Ambient Air Quality Standard (NAAQS)

3.5 Trace Elements

Metal concentrations in µg/m^3 associated with PM_{10} are presented in Table 10. The concentration of Pb among the residential areas ranged between 0.09 (Vikas Nagar) to 0.25 (Gomati Nagar) µg/m^3 with an average of 0.16 µg/m^3. Wherein commercial areas, the values ranged between 0.22 (Alambagh) to 0.41 (Charbagh) µg/m^3 with an average of 0.31 µg/m^3. In an industrial area Amausi**,** the value of Pb was 0.32 µg/m^3.

Besides, the concentration of Ni among the residential areas ranged between 3.5 (Vikas Nagar) to 7.4 (Gomati Nagar) ng/m^3 with an average of 5.33 ng/m^3. Wherein commercial areas, the values ranged between 8.2 (Alambagh) to 12.8 (Charbagh) ng/m^3 with an average of 10.28 ng/m^3. In an industrial area Amausi**,** the value of Ni was 8.5 ng/m^3.

However, all the values of Pb and Ni were within the prescribed NAAQS (Refer Table 10) for all monitoring locations.

Table 10: Metal concentration associated with PM_{10}

S. No.	Location	Pb, µg/m^3	Ni, ng/m^3
1	Aliganj	0.12	4.1
2	Vikas Nagar	0.09	3.5
3	Indira Nagar	0.19	6.3
4	Gomati Nagar	0.25	7.4
Average		**0.16**	**5.33**
5	Charbagh	0.41	12.8
6	Alambagh	0.22	8.2
7	Aminabad	0.26	9.5
8	Chowk	0.35	10.6
Average		**0.31**	**10.28**
9	Amausi	0.32	8.5
NAAQS		**1$^{\#}$**	**20***

#: 24-hour Average, and *: Annual Average

3.6 Noise Level

The noise monitoring data recorded during the post-monsoon period (September-October, 2024) is presented in Table 11. In the residential areas, the day and night noise levels were recorded with the range from 39.5 to 86.5 and 36.4 to 82.4 dB(A) respectively. All the average values were significantly higher than the prescribed national limits of 55 and 45 dB (A) for day and night, respectively.

In the commercial areas, the day and night noise levels were recorded with the range from 58.2 to 95.4 and 55.8 to 81.5 dB(A), respectively. Noise levels at all the commercial sites were significantly higher than the prescribed national limits of 65 dB (A) and 55 dB (A) for day and night, respectively. In an industrial area Amausi, the day and night noise levels were recorded 78.4 and 72.4 dB(A) respectively. Noise levels at an industrial area was recorded higher than the NAAQS of 75.0 and 70.0 dB(A) respectively.

Table 11: Noise level dB(A) during day and night time

Location	Range	Day	Night
Aliganj	Min	44.7	40.3
	Max	73.5	70.8
	Avg. (Leq)	**67.5**	**64.9**
Vikas Nagar	Min	39.5	36.4
	Max	70.3	68.5
	Avg. (Leq)	**62.4**	**58.4**
Indira Nagar	Min	40.5	36.4
	Max	83.8	79.4
	Avg. (Leq)	**71.3**	**68.5**
Gomati Nagar	Min	45.3	38.9
	Max	86.5	82.4
	Avg. (Leq)	**72.8**	**70.5**
NAAQS for Residential Area		**55**	**45**
Charbagh	Min	62.5	59.3
	Max	84.5	81.5
	Avg. (Leq)	**78.3**	**72.5**
Alambagh	Min	58.2	59.9
	Max	76.4	72.7
	Avg. (Leq)	**73.5**	**70.2**
Aminabad	Min	61.4	55.8
	Max	82.7	78.5
	Avg. (Leq)	**75.2**	**72.4**
Chowk	Min	67.2	61.3
	Max	95.4	81.4
	Avg. (Leq)	**86.9**	**73.4**
NAAQS for Commercial Area		**65**	**55**
Amausi	Min	55.4	50.9
	Max	86.3	78.4
	Avg. (Leq)	**78.4**	**72.4**
NAAQS for Industrial Area		**75**	**70**

4.0 Trends of Ambient Air quality in Lucknow City

The observed PM_{10}, $PM_{2.5}$, SO_2, and NO_2 for the past 5 years of post-monsoon seasonal data (i.e., from 2020 to 2024) have been compared to find out the prevailing trend of air pollution in Lucknow city (Figures 4-7). Overall, there is a slight increase observed in the air quality trend, particularly in commercial sites in the city which is attributed to some local environmental, urban development, and climatic factors.

4.1 Trend of PM_{10} and $PM_{2.5}$

Figure 4 indicates that the PM_{10} concentration is observed to increase from 2020 to 2022, and followed years i.e., in 2023 and 2024 PM_{10} concentration is decreased in residential and commercial areas. The levels of PM_{10} in commercial areas were identified as relatively higher values but in residential and industrial areas the values were lower when compared to post-monsoon monitoring data of the previous year 2023 and all the sites shows exceeded the NAAQS.

Figure 5 indicates that the $PM_{2.5}$ concentration is observed to increase from 2020 to 2022, and in the following year of 2023, the values were decreased. However, in 2024 the $PM_{2.5}$ concentration was identified as relatively higher values at all locations when compared to post-monsoon monitoring data of the previous year 2023, and all the sites shows exceeded the NAAQS.

4.2 Trend of SO_2 and NO_2

The trend of SO_2 and NO_2 for Post-monsoon seasons from 2020 to 2024 is presented in Figure 6 and Figure 7 for all the locations in the city. The overall concentration SO_2 and NO_2 showed a decrease from 2023 to 2024, however, before the 2023 year, the trend of SO_2 and NO_2 had an increment. All the values of SO_2 and NO_2 were found to be lower than the NAAQS.

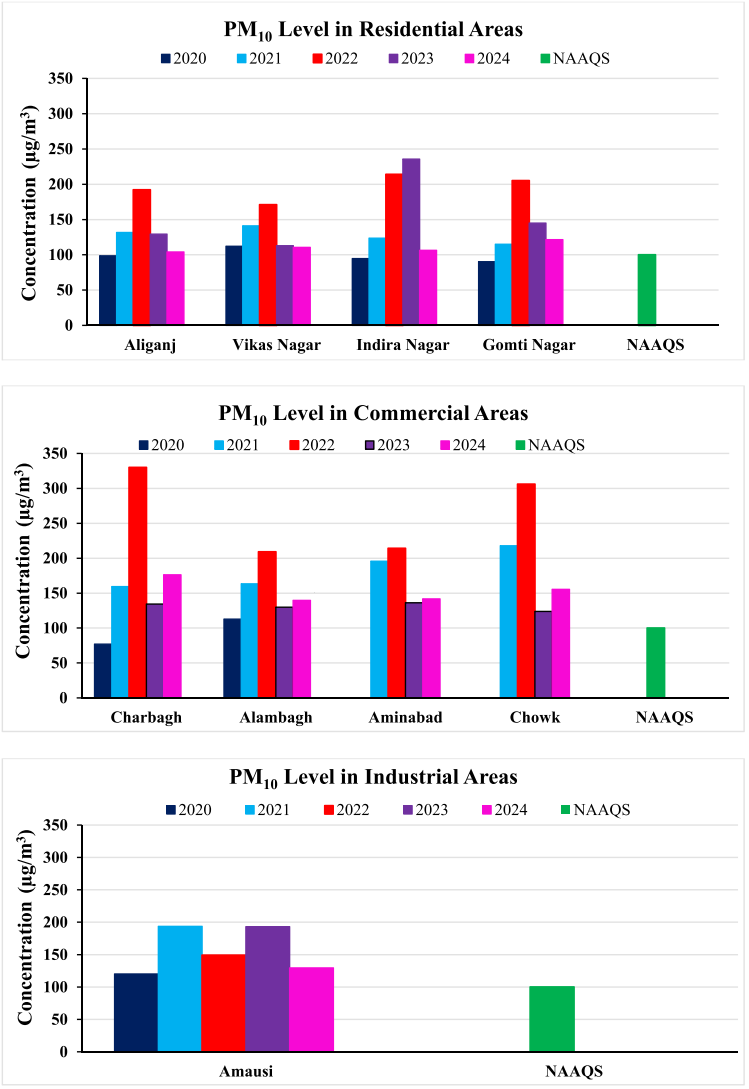
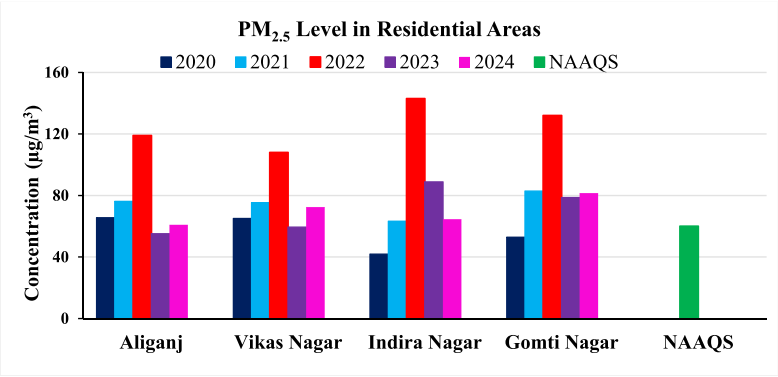
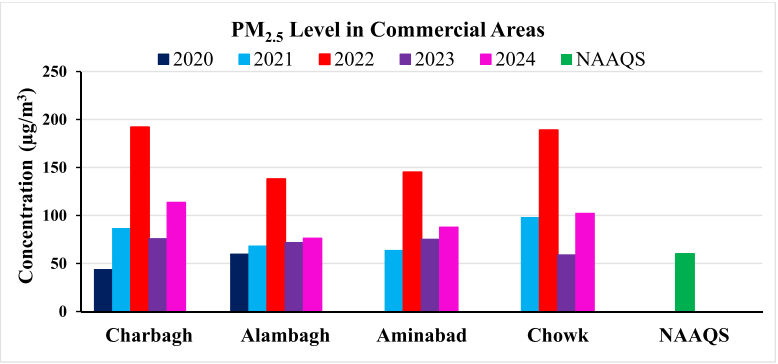


Figure 4: Concentration (µg/m^3) of PM_{10} **(RSPM)** in residential, commercial and industrial areas of Lucknow city during 2020 to 2024 (post-monsoon) and compared with prescribed National Ambient Air Quality Standard (NAAQS)





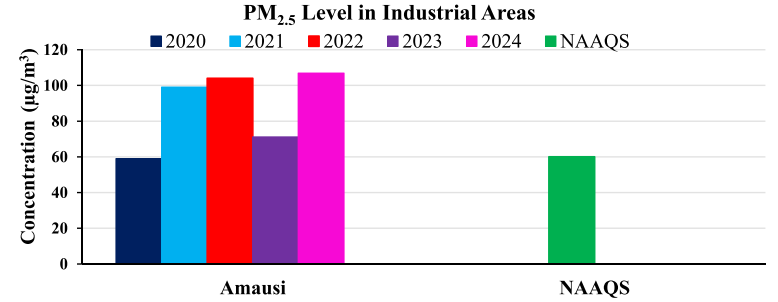
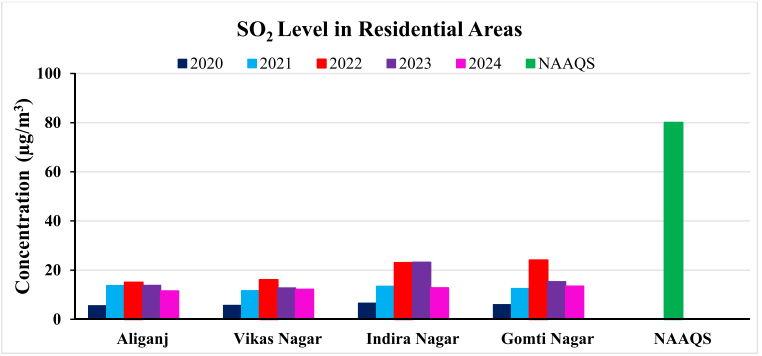
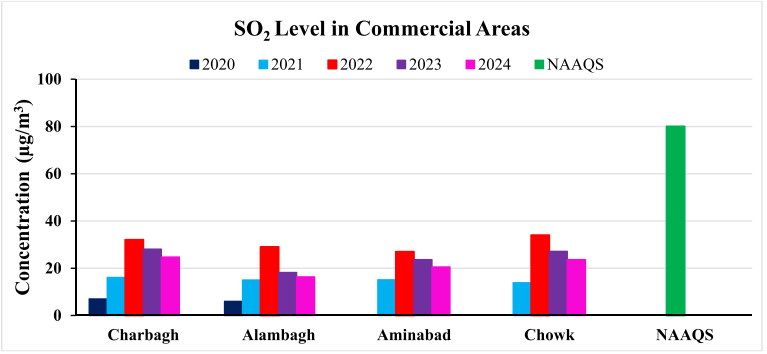


Figure 5: Concentration (µg/m^3) of $PM_{2.5}$ in residential, commercial and industrial areas of Lucknow city during 2020 to 2024 (post-monsoon) and compared with prescribed National Ambient Air Quality Standard (NAAQS)





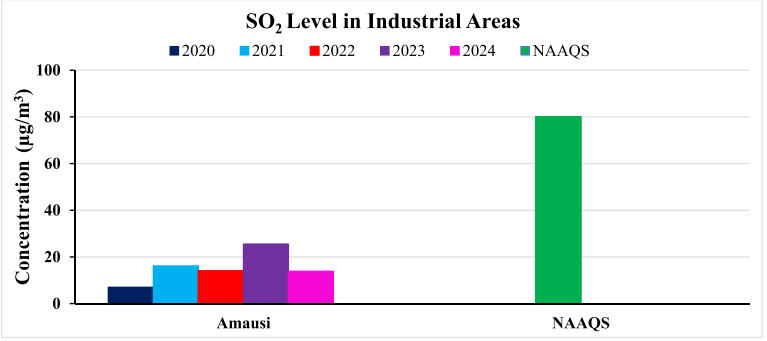


Figure 6: Concentration (µg/m^3) of SO_2 in residential, commercial and industrial areas of Lucknow city during 2020 to 2024 (post-monsoon) and compared with prescribed National Ambient Air Quality Standard (NAAQS)

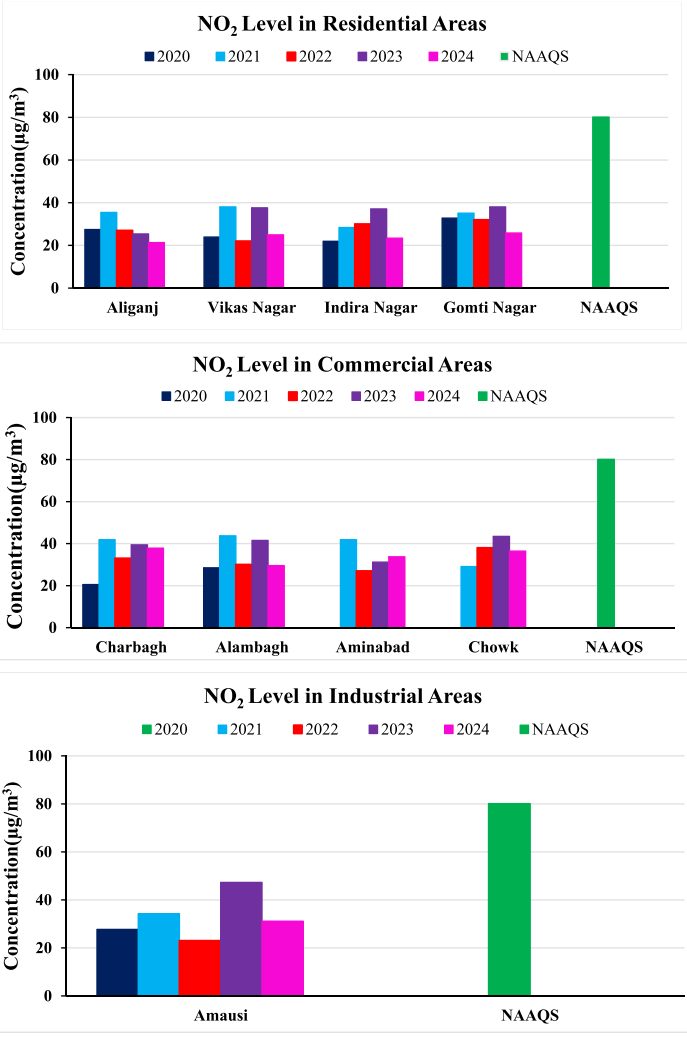


Figure 7: Concentration (µg/m^3) of NO_2 in residential, commercial and industrial areas of Lucknow city during 2020 to 2024 (post-monsoon) and compared with prescribed National Ambient Air Quality Standard (NAAQS)

4.3 Trend of Noise Level

Current year's post-monsoon 2024 noise data was compared with the corresponding data of the previous five years (i.e. 2020 to 2024) and results are presented in Figure 8 and 9. The higher noise levels adversely affect the lives of millions of people in the city. Studies have shown that there are direct links between noise and health.

4.3.1 Day and Night Time Noise Level

All residential, commercial, and industrial areas showed a slight increase in Day and Night time noise levels till 2022 and in the following year 2023, decreased day and night noise levels were observed. However, as compared to 2023 the day and night noise levels increased in 2024. The day and night time comparative data are presented in Figure 8 and Figure 9, respectively.

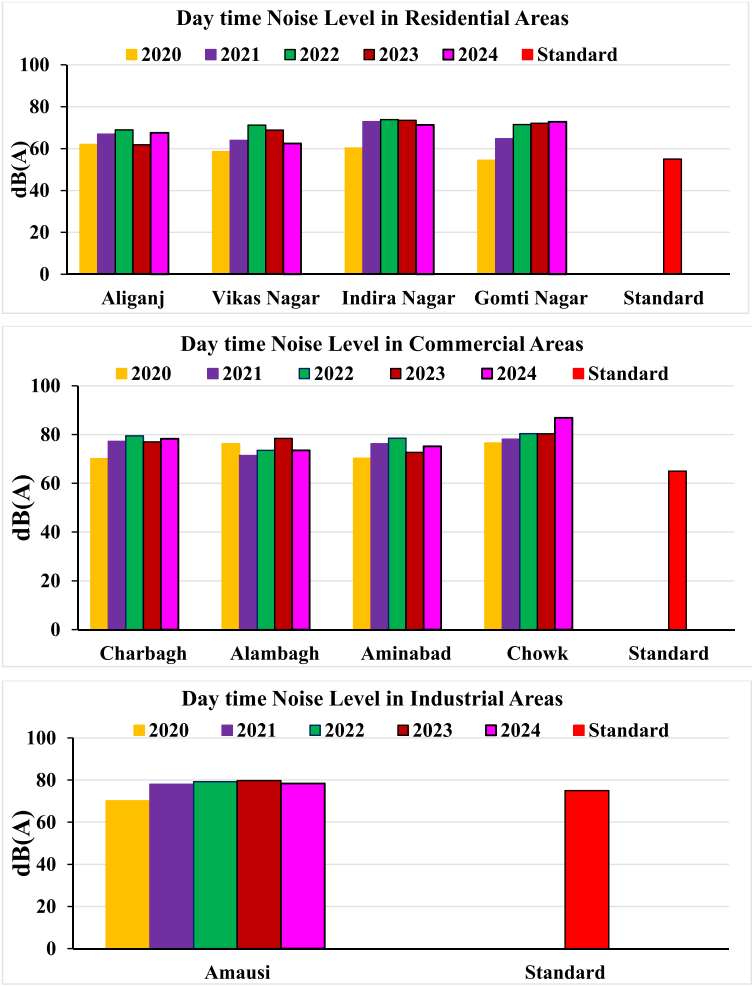


Figure 8: Comparison of day time Noise Level in dB(A) for different areas of Lucknow city (post-monsoon 2020-2024)

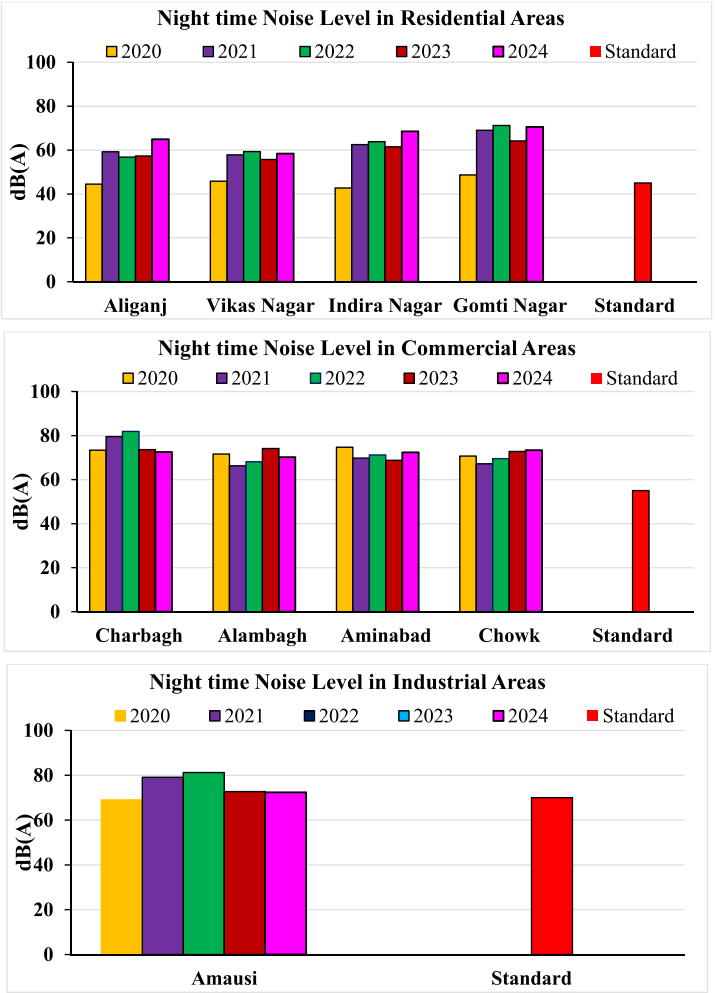


Figure 9: Comparison of night time Noise Level in dB(A) for different areas of Lucknow city (post-monsoon 2020-2024)

5.0 Conclusions / Main Findings

CSIR-IITR has evaluated the status of air quality for the period of September -October 2024 (i.e., post-monsoon) through the monitoring and analysis of ambient PM_{10}, $PM_{2.5}$, SO_2, NO_2, and toxic heavy metals i.e., Lead (Pb) and Nickel (Ni) associated with PM_{10} at 9 locations which are grouped into 3 categories i.e., Residential, Commercial, and Industrial areas in Lucknow. Besides, day and night Noise Levels were also monitored at these 9 locations in the city. The main findings from the study are given below:

The 24-hour concentrations of PM_{10} in Lucknow city ranged from 42.8 µg/m^3 to 248.3 µg/m^3 with an average of 131.1 µg/m^3 while in the case of $PM_{2.5}$, the 24-hour concentrations ranged from 29.5 µg/m^3 to 201.3 µg/m^3 with an average of 90.5 µg/m^3. The comparison of concentration trend analysis shows that mean PM_{10} levels decreased by 23.1% and 32.9% in residential, and industrial sites respectively, while over commercial areas increased by 17.1% from post-monsoon 2023 to post-monsoon 2024. However, in mean $PM_{2.5}$ the levels increased by 2.1%, 36.7%, and 50.2% over the respective residential, commercial, and industrial sites from post-monsoon 2023 to post-monsoon 2024. Irrespective of locations, the average values of PM_{10} and $PM_{2.5}$ were found everywhere exceeded the NAAQS permissible limits of 100 µg/m^3 and 60 µg/m^3 respectively. Overall, in the city, the average concentration exceedance was observed at a maximum of up to 0.31 times in PM_{10} and 0.41 times in $PM_{2.5}$ than the prescribed NAAQS limits. Whereas, the trace metals (i.e. Pb and Ni) which are associated with PM_{10} in the city are found in the range 0.09 – 0.41 µg/m^3 with an average of 0.26 µg/m^3 for Pb, and the range 3.5-12.8 ng/m^3 with an average of 8.03 ng/m^3 for Ni. The 24-hour concentrations of SO_2 in Lucknow city ranged from 7.3 to 29.4 µg/m^3 with an average of 15.8 µg/m^3 while the 24-hour concentrations of NO_2 ranged from 10.2 to 58.4 µg/m^3 with an average of 29.7 µg/m^3. The values of SO_2 and NO_2 decreased by 25.7 % and 24.7 %, respectively from post-monsoon 2023 to 2024. However, average values of SO_2 and NO_2 were well below the permissible NAAQS limits of 80 µg/m^3.

The day-time and night-time noise levels ranged from 39.5 to 86.5 dB(A) and 36.4 to 82.4 dB(A) respectively in residential areas, and ranged from 58.2 to 95.4 dB(A) and 55.8 to 81.5 dB(A) in commercial areas respectively. These mean noise values were above their respective day-time standard of 55 dB(A) and night-time standard of 45 dB(A) for residential areas and day-time standard of 65 dB(A) and night-time standard of 55 dB(A) for commercial areas respectively as per CPCB standards. At an industrial area Amausi, the day-time and night-time noise levels were 78.4 dB(A) and 72.4 dB(A) respectively. The noise measurements are above the national standard of 75 dB(A) for day-time and 70 dB(A) for night-time which are recommended for Industrial sites.

The post-monsoon air quality survey results were significantly influenced by the rains of monitoring days. There is a decreased concentration level of particle pollution in the city was observed in comparison with the pre-monsoon 2024. The monsoon rains scavenge the particles in the atmosphere and the wet surface controls dust from its resuspension to ambient air. During the post-monsoon, the increased atmospheric humidity can lead to the agglomeration of particles which makes the particles heavier and deposited on the ground from the atmosphere. The activities in the city like construction, markets, and movement of vehicles are also reduced due to the effect of rains. However, the yearly increment of registered vehicular numbers and fuel consumption in the city has a likely impact on slightly exceeded air pollution concentration than their national standards.

Air pollution is a changing phenomenon with respect to location and time due to fluctuating natural and man-made activities. Continuous awareness of the status of city air quality, and efforts by the individual and government communities are essential for the safe-guard of public health.

6.0 Health Impacts of Air and Noise Pollution

Air pollution levels have shown increasing trends due to rapid urban development and modernization in the country. Researchers have recently begun to pay more attention to explore and establish the association between air pollution and respiratory system diseases. Studies in toxicology, epidemiology, and other related fields have demonstrated that respirable particles are closely related to the incidence of human diseases and mortality rate.

Particulate Matter (PM_{10} & $PM_{2.5}$)

Fine airborne particulate matter for the diameter $\leq$ 2.5 µm, when inhaled would penetrate beyond the larynx. The $PM_{2.5}$ (particles less than 2.5 micrometers in diameter) can penetrate deeply into the lung, irritate and corrode the alveolar wall, and impair lung function, cause emphysema and bronchitis, and aggravate existing heart disease. Ultrafine particles ranging from 0.001 to 0.1 micron in diameter are able to penetrate deep into the lungs and to alveolar sacs where gaseous exchange occurs. Particles increase the rates of blood flow and vascular permeability to white blood cells, elevating clotting activity, constriction of the airways and fever induction.

Sulfur Dioxide (SO_2)

Increased SO_2 may cause irritation of 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 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 may result in loss of vision and severe burns. Repeated or prolonged exposure to moderate concentrations may cause inflammation of the respiratory tract, wheezing and lung damage.

Oxides of Nitrogen (NO_x)

Various compounds and derivatives in the family of NO_2 including NO_2, HNO_3, NO, nitrates and nitric oxide cause a variety of health impacts. 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 bronchitis. Industrial exposures to nitric oxide can cause unconsciousness and vomiting. 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.

Trace element-Lead (Pb)

Lead is a neuro-toxin causing impairment of neurodevelopment in children, effects development of brain of the fetus. Mortality in workers exposed to high level of lead is increased. Decreased nerve conduction velocity, cognitive development and instinctual performance, hearing loss, jaundice, anemia in children. Cognitive and neuro-behavioral deficits are seen in children at low levels of exposure.

Trace element-Nickel (Ni)

The harmful human health effect of nickel are an allergic reaction, chronic bronchitis, reduced lung function, lung cancer and nasal sinus cancer. Animal studies have found increase in newborn deaths and decrease in newborn weight after ingesting Nickel.

Noise

Noise pollution is the spread of unwanted sounds into the environment. Unwanted sounds have a range of mental health effects. The brain is always monitoring sounds for signs of danger, even during sleep. With continued exposure to noise pollution can trigger anxiety or stress. Problems related to noise include stress related illnesses, high blood pressure, speech interference, hearing loss, sleep disruption, and lost productivity. People living with noise pollution may feel irritable, on edge, frustrated, or angry. If a person feels they cannot control the amount of noise in their environment, its impact on their mental health intensifies.

7.0 Recommendations for Mitigation of Air Pollution in Lucknow

1. Social awareness programs to sensitize public about the clean air practices.
2. Encouraging electric/biodiesel/CNG/ hybrid vehicles for public transport.
3. Installation of more electric vehicle charging stations
4. Removal of more than ten years old vehicles from city roads.
5. Efficient operation of traffic signal systems and traffic control by traffic police.
6. Synchronize consecutive traffic signals to facilitate smooth traffic on crossing.
7. Strict control on haphazard roadside parking to avoid traffic jams.
8. Relocation of roadside venders at suitable location to avoid traffic jams.
9. Encouragement for carpooling and use of public transport by daily commuters.
10. Strict control on overloading and proper covering to avoid spillage from trucks carrying garbage, solid wastes, sand, cement or any loose material.
11. Installation of Vehicle Scrap Plants for old and phased-out vehicles.
12. Regular vacuum-assisted sweeping and water sprinkling on roads to prevent the resuspension of road dust.
13. Maintaining shrubs plantation on dividers of roads.
14. Installing proper HDPE construction nets/meshes to restrict fugitive dust spread from building construction and demolition activities.
15. Ensuring continuous electric power supply to avoid use of diesel generators.
16. Encourage electrical or gas-based crematorium practices to avoid fire wood burning.
17. Regular Municipal Solid Waste collection and disposal in time-bound manner.
18. Complete ban on burning of plastic, trash, garbage, solid waste or any material in open and uncontrolled manner.
19. Avoid burning of crop residues and train farmers to use technologies to convert waste into useful products, fuel or manure.
20. Regular fogging on roads with higher load of air pollution.
21. Use of energy efficient equipment to reduce carbon emissions in sectors such as transport, manufacturing/production and agriculture etc.
22. Installation of efficient solar power stations on roof top of all the buildings of city.
23. Ban loudspeakers with high decibels noise levels.

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Contributors to the Study:

The survey, sampling, data analysis, and report preparation are done by the following team of the Environmental Monitoring Laboratory, ASSIST Division, CSIR-IITR

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ASSIST Division Head: Dr V. P. Sharma

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CSIR-INDIAN INSTITUTE OF TOXICOLOGY RESEARCH

"सामूहिक सफलता में ही प्रत्येक व्यक्ति की सफलता निहित है।" "Until all of us have succeeded, none of us have"




अनुसंधान एवं विकास प्रभाग

- खाद्य, औषधि, पर्यावरण और प्रणाली विषविज्ञान (FEST)
- विश्लेषणात्मक विज्ञान, सेवाएं और तकनीकी समाधान के माध्यम से औद्योगिक सहायता (ASSIST)
- विनियामक और कम्प्यूटेशनल विषविज्ञान (ReaCT)

अनुसंधान क्षेत्र

- खाद्य, औषधि और रासायनिक विषविज्ञान
- पर्यावरण विषविज्ञान
- नियामक विषविज्ञान
- टॉक्सिकोइंफॉर्मेटिक्स एवं औद्योगिक अनुसंधान
- प्रणाली विषविज्ञान एवं स्वास्थ्य आपदा मूल्यांकन

उद्योग और स्टार्टअप के लिए आर एंड डी साझेदारी

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सेवाएं दी गईं

- जीएलपी प्रमाणित पूर्व–नैदानिक विषाक्तता अध्ययन
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- जल गुणवत्ता मूल्यांकन और निगरानी
- विश्लेषणात्मक सेवाएं
- पर्यावरण निगरानी और प्रभाव मूल्यांकन
- रसायनों/उत्पादों के बारे में जानकारी
- कम्प्यूटेशनल भविष्य कहनेवाला विषाक्तता मूल्यांकन

मान्यताएं

- वैज्ञानिक और औद्योगिक अनुसंधान संगठन (एसआईआरओ)
- यूपी प्रदूषण नियंत्रण बोर्ड (जल और वायु)
- भारतीय कारखाना अधिनियम (पीने का पानी)
- भारतीय मानक ब्यूरो (सिंथेटिक डिटर्जेंट)
- भारतीय खाद्य सुरक्षा और मानक प्राधिकरण (FSSAI)

विकसित/उपलब्ध प्रौद्योगिकियां

- ओनीर– सुरक्षित पेयजल के लिए एक नया समाधान
- पोर्टेबल जल विश्लेषण किट
- पर्यावरण और मानव स्वास्थ्य के लिए मोबाइल प्रयोगशाला
- सरसों के तेल में आर्जीमोन की त्वरित जांच के लिए एओ किट
- मक्खन पीले रंग का पता लगाने के लिए एमओ जांच, एक मिलावटी, खाद्य तेलों में
- सेन्ज़एचबी® – एक रैपिड हीमोग्लोबिन परीक्षण किट
- अटेस्ट – दूध में मिलावट का पता लगाने वाली किट
- अटेस्ट – खाद्य तेल परीक्षण किट
- अटेस्ट – फल–रस ताजगी परीक्षण किट
- रेस्पॉन्स – बहुसंकेतन परीक्षण उपकरण
- वेलसेन्स® – इंटेलिजेंट पैकेजिंग समाधान
- मिल्कचेकर
- फ्लोरीपीसीआर®– फ्लोरीमीटर के साथ थर्मोसाइक्लर को एकीकृत करने वाला एक प्लेटफॉर्म उपकरण

R & D Divisions

- Food, Drug, Environment & Systems Toxicology (FEST)
- Analytical Sciences & Services and Industrial Support through Technological Solutions (ASSIST)
- Regulatory and Computational Toxicology (ReaCT)

Research Areas

- Food, Drug & Chemical Toxicology
- Environmental Toxicology
- Regulatory Toxicology
- Toxicoinformatics & Industrial Research
- Systems Toxicology & Health Risk Assessment

R & D Partnership for Industries & Startup

- Centre for Innovation and Transnational Research (CITAR-BIRAC-BioNEST)
- DSIR-IITR-CRTDH Environmental Monitoring and Intervention Hub

Services Offered

- GLP certified pre-clinical toxicity studies
- NABL (ISO/IEC 17025:2017) accredited Safety/ toxicity evaluation of NCEs
- Water quality assessment and monitoring
- Analytical services
- Environmental monitoring and impact assessment
- Information on chemicals/ products
- Computational predictive toxicity assessment

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 Butter Yellow, an adulterant, in edible oils
- SenzHB® - A Rapid haemoglobin test kit
- Attest - Milk adulteration detection kit
- Attest - Edible oil test kit
- Attest - Fruit-juice freshness test kit
- Response - Multiplexed testing device
- Wellsens® - Intelligent packaging solutions
- MilkAchecker
- FluoriPCR® - A platform device integrating thermocycler with fluorimeter

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