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Assessment of ambient air quality of Lucknow city post monsoon 2023

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Abstract

This study monitoring and assessment of air pollutants, including lead and nickel trace metals, gases such as sulphur dioxide (SO_2) and nitrogen dioxide (NO_2), and respirable suspended particulate matter (PM_{10}) and fine particulate matter ($PM_{2.5}$), were done at nine locations that were divided into three categories: residential, commercial, and industrial of the ambient air quality in the city of the post-monsoon. With an average of 148.9 μg m^{-3}, the 24-hour concentrations of PM_{10} ranged from 58.5 to 337.8 μg m^{-3}, whereas the 24-hour concentrations of $PM_{2.5}$ ranged from 32.5 to 118.4 μg m^{-3}, with an average of 70.5 μg m^{-3}. At every location, the mean concentrations of PM_{10} exceeded the allowable threshold of 100 μg m^{-3}. While $PM_{2.5}$ levels, with the exception of Aliganj, Vikas Nagar, and Chowk, exceeded the 60μg m^{-3} national limit. Pb and Ni, which are PM_{10} trace elements, range from 0.0028 to 0.0370 μg m^{-3}, with an average of 0.0147 μg m^{-3} for Pb and 1.30 to 11.75 μg m^{-3}, with an average of 6.62 μg m^{-3} for Ni. During a 24-hour period, the levels of SO_2 varied between 7.9 and 57.7 μg m^{-3}, with an average of 20.8 μg m^{-3}. Conversely, the levels of NO_2 varied between 9.3 and 89.0 μg m^{-3}, with an average of 37.8. Between μg m^{-3} the post-monsoon of 2022 and 2023, SO_2 concentrations declined by 16.0% and NO_2 values increased by 22.0%, respectively. On the other hand, average SO_2 and NO_2 levels were significantly lower than the 80μg m^{-3}permitted limits set by the CPCB (NAAQS-2009).

Keywords PM_{10}; $PM_{2.5}$; SO_2; NO_2; NAAQS; Human health

1. Introduction

Three major types of environmental pollution are pollutants in the air, water, and land contamination. In addition, pollution can also refer to particular pollutants like plastic or radioactive elements or to excessively human activity like light and noise pollution. See this infographic to learn more [1,2]. Change in the climate is mainly brought about by air pollution. The greenhouse effect is the result of human actions like the burning of fossil fuels and extensive forest clearing, which raise atmospheric carbon dioxide levels and trap heat inside the atmosphere [3]. Sea levels and changes in the climate are affected by this [1,4].

The issue of air pollution is getting worse every day. Infrastructure, population expansion, urbanization, and industrialization all have a direct influence on it. Large-scale public gatherings for sporting events, cultural and musical festivals, and other events necessitate the creation of air pollution sources [5]. These sources release a mixture of pollutants into the atmosphere, which ultimately exposes humans and other living things to these pollutants. "Any solid, liquid, or gaseous substance present in the atmosphere in such concentration as may be or tend to be harmful to humans or other living creatures or plants, or to property or environment" is the definition of air pollution as given by the Air (Prevention and Control of Pollution) Act of 1981 [6].

Contaminants are defined as inputs of alien and potentially toxic substances into the environment, such as chemical or microbial contaminants, whereas pollutants are defined as anthropogenically-introduced substances that pollute water

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or the atmosphere or that have negative effects on the environment. Nonetheless, the Earth's atmosphere contains a range of gases that are essential to life support. The majority of dry air's volume is made up of major gases like oxygen and nitrogen, with the remaining gases—argon, carbon dioxide (CO_2), and many more—making up only 1% of the total. The atmosphere gives us oxygen to breathe and shields us from much of the harmful ultraviolet (UV) radiation from the Sun [7].

Environmental pollution poses a grave threat to the delicate balance of ecosystems and human health, with wastewater being a significant contributor [8]. Wastewater, laden with various pollutants from industrial, agricultural, and domestic sources, when discharged untreated into water bodies, contaminates aquatic habitats and endangers aquatic life. Additionally, it poses serious health risks to humans through the consumption of contaminated water and seafood [9]. Therefore, the necessity of wastewater treatment cannot be overstated. Treatment processes like filtration, biological degradation, and chemical treatment are essential to remove harmful contaminants, pathogens, and nutrients from wastewater before its release back into the environment. Proper wastewater treatment not only safeguards human health but also preserves the integrity of ecosystems, ensuring the sustainability of vital natural resources for future generations [10].

The main types of air pollutants found in metropolitan areas are particulate aerosols, which include suspended particulate matter (>10μm), respirable particulate matter (RSPM)≤10μm, and nanoparticles ≤0.1 μm. Because of their smaller size and relatively higher surface area compared to larger-size particles, particles less than 2.5μm are regarded as more dangerous and represent a greater risk to human health. They incite bronchitis, asthma, and other respiratory and cardiovascular disorders by penetrating the alveolar sac. The main pollutants, such as PM_{10}, $PM_{2.5}$, SO_2, NO_2, O_3, CO, HC, and PAHs, are the main sources of damage to the environment, human health, and climate. The local sources that release pollutants into the surrounding environment play a significant role in these primary pollutants [11].

Our regulatory agencies working for a better environment have taken several steps to curb and control the detrimental effects of air pollution and climate change. Scientists, decision-makers, and the general public are also aware of the environmental changes and the related impacts. There has been an increasing level of fine particulate matter from various sources in most cities [12,13]. The National Clean Air Programme (NCAP) of MoEF & CC has identified 131 non-attainment cities in 23 states, including Lucknow, to reduce the predominant ambient air pollutants, particularly fine particulate matter concentration by 2024 [14].

In order to ascertain if the city's present load of various pollutants is within allowed limits or still requires the implementation of appropriate abatement measures in order to comply with rules, regular monitoring and surveys of the seasonal air quality status are required. In this regard, the CSIR-Indian Institute of Toxicology Research (IITR), Lucknow, has been carrying out air quality surveys in Lucknow city since 1997 for the pre-monsoon (April-May) and post-monsoon (September-October) seasons in order to ascertain the ambient noise pollution levels, trace metal concentrations (Pb and Ni), gaseous emissions (SO_2 and NOx), and ambient particulate matter (PM_{10} and $PM_{2.5}$) [15].

Air pollution is the term used to describe the presence of various gases, foreign particles, and contaminants in the air at quantities high enough to endanger human health and aggravate a range of respiratory disorders in living things. Nitrogen pollution is the primary cause of harm to human health, climate change, and the environment. particle matter (PM_{10}, $PM_{2.5}$), sulphur dioxide, and nitrogen dioxide [16]. 99 percent of people on the planet breathe air that is overly polluted and exceeds WHO guidelines, with low- and middle-income countries having the greatest exposures. This information comes from WHO data. Air pollutants such as particulate matter (PM), nitrogen oxides (NOx), sulphur dioxide (SO_2), and ground-level ozone (O_3) frequently above the National Ambient Air Quality Standards [17,18].

PM, a major air pollutant created by both artificial and natural sources, is one of the main causes of Lucknow City's deteriorating ambient air quality. Aerodynamic diameter is used to categories PM into fine (PM2.5) size fractions. The main causes of PM in Lucknow include road dust, construction, burning fossil fuels, burning biomass, and diesel generator emissions from vehicles. Significant amounts of the detected PM concentration are also derived from secondary sources, like the atmosphere [19].

The size and population of Lucknow, the capital and largest city of the Indian state of Uttar Pradesh, are expanding quite quickly. It is projected that there are currently 35 lakh people living there. In India, Lucknow ranks tenth and twelfth in terms of population density among urban agglomerations. bordered by Barabanki to the east, Unnao to the west, Raebareli to the south, and Unnao to the north. Lucknow is situated on the northwest bank of the Gomti River, between Sitapur and Hardoi. The city is split into the Cis and Trans Gomti regions by the river that runs through it. The city is located 404 feet (123 meters) above sea level. Before 88 villages were included in the municipal boundaries in December 2019, the area of Lucknow city was 402 km^2. As a result, the city's total area grew to 631 km^2. As the seat of power for the Nawabs in the 18th and 19th centuries, Lucknow has always been a heterogeneous city that thrived as a centre of North Indian culture and the arts. It is still a major hub for politics, business, education, technology, design, aerospace, finance, government, tourism, culture, music, and poetry [20].

The following objectives are delineated for the post-monsoon 2023 study:

- To study the air quality status of post-monsoon season at different locations
- 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

2. Monitoring Locations and Methodology

Between the latitudes of 26°30'N and 27°10'N and the longitudes of 80°30'E and 81°13'E is where Lucknow City is situated. It is the capital of the most populous state in India, Uttar Pradesh. It is situated in the middle of the Indus-Gangetic Plain and is within a seismic zone.

Lucknow City is experiencing a surge in urbanization due to rising investments in real estate, education, technology, and other commercial and industrial activities. The Road Transport Office (RTO) in Lucknow reports that as the population grows, so does the number of registered cars [21].

For the post-monsoon 2023 (September–October) investigation, nine air quality monitoring locations representing various activities and encompassing residential, commercial, and industrial regions were chosen. The methods used are listed in Table 2 and are summarized in Fig.1

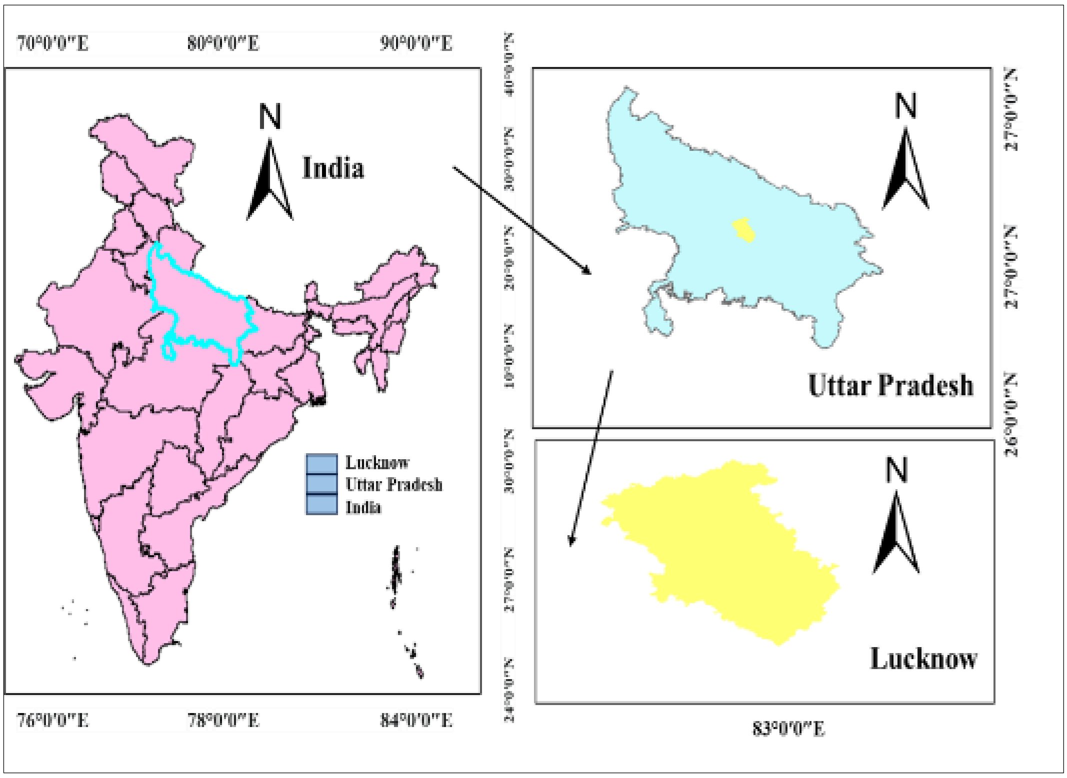


Figure 1 Study area

2.1. Vehicular Inventory and Fuel Consumption in the City

An inventory of the city of Lucknow's vehicles and fuel usage was conducted, and as of June 1, 2023, primary data was gathered from RTO (Table 1). When compared to the car data from 2022, the total number of registered vehicles increased by 6.3% by 2023. By 2023, there would be 68 and 196 CNG (compressed natural gas) and electricity buses operating for UPSRTC, respectively. There are 230 fuel outlets (i.e., petrol, diesel and CNG) in Lucknow, which are provided by various oil and gas businesses. The fuel consumption for the years 2022 and 2023. It shows that while LPG usage fell by 32.4%, that of petrol, diesel and CNG climbed by 23.7%, 24.9 and 22.2%, respectively [22].

Table 1 Comparison of registered vehicle numbers in Lucknow

SI. No.	Type of vehicle	No. of Registered vehicle in 2022-2023	% Increase
1	Multi articulated	7879	4.5
2	Light medium, Heavy weight	61273	7.7
3	Light commercial vehicles	4072	3.9
4	Buses	5076	5.9
5	Taxi	63648	24.4
6	Omni buses	551	0.7
7	Light Motor vehicle	11250	1
8	Two wheelers	2012386	4.2
9	Car	394333	11.7
10	Jeep	150365	19.1
11	Tractors	30899	6.0
12	Trailers	2174	3.4
13	Others	71976	0.2
14	Total	2812328	6.3

2.2. Study Rationale

Like many other Indian towns, Lucknow is experiencing an increase in air pollution. The city's poor air quality has been caused throughout time by particulate matter from several sources. The use of CNG, e-vehicles, and BS-VI compliant automobiles on city roadways, along with other air pollution mitigation measures, may have an effect on the city's air quality. The authorities have also taken up the installation of appropriate traffic signals to regulate vehicle movements. Nonetheless, the air quality has been impacted by traffic congestion at several signals and cars operating in idle mode. The demand for open cooking and street food vendors has also increased due to an increase in urban population and economic activity. This has raised the emission load associated with cooking combustion into the surrounding air. The issue is frequently made worse by the prevalence of widely dispersed area (fugitive) sources in urban areas as well as the ignorance surrounding the origins, production, and movement of secondary aerosols [19].

Old buildings are being demolished and excavation is being done for new construction or foundations in various parts of Lucknow, which is a major source of dust. The sources of dirt and road dust are also the broken and unpaved roadways. Despite the State Government's numerous efforts, like as the Swachh Bharat Abhiyan's cleaning programmes, large waste and garbage dumps can be found in many of the city's peripheral regions, contributing to air pollution. The air pollution is also a result of the fugitive sources that are located along the roads [23].

Therefore, it is extremely important to be aware of the latest status of air pollution in the city to understand the sources and receptor linkages and implement cost-effective strategies for emission reduction. To address air pollution of Lucknow city, CSIR-IITR has been conducting air quality surveys at 9-locations across Lucknow city since 1997, and regularly identifying the sources, developing their inventory of emissions and generating air pollution data for public awareness and to support in government policy making. Post-monsoon 2023 (September to October) air quality survey at 9 locations in Lucknow covering industrial, residential and commercial areas has been carried out with respect to PM_{10}, $PM_{2.5}$ SO_2, NO_2, trace metals (Pb and Ni), and noise pollution and this report illustrate the results with a scientific discussion and recommendations.

3. Results and Discussion

The detailed results of air quality monitoring during the post-monsoon period are presented in Table 2 and Fig. 2.

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

In residential areas (Aliganj, Vikas Nagar, Indira Nagar and Gomti Nagar), the 24 hours concentrations of PM_{10} were in the range of 58.5 to 310.9 µg m^{-3} with an average of 155.7 µg m^{-3}. The average concentration of PM_{10} was observed highest at Indira Nagar among the residential areas.

In commercial areas (Charbagh, Alambagh, Aminabad, and Chowk) the concentrations were in the range of 66.4 to 194.9 µg $m^{-3}$with an average of 131.0 µg m^{-3} respectively. The average concentration of PM_{10} was observed highest at Aminabad among the commercial areas.

In industrial area (Amausi), the average concentration of PM_{10} was 192.9 µg m^{-3}. However, in all locations PM_{10} levels were 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 Gomti Nagar), the 24 hours concentrations of $PM_{2.5}$ were in the range of 32.5 to 118.4 µg m^{-3} with an average of 70.5 µg m^{-3}. The average concentration of $PM_{2.5}$ was observed highest at Indira Nagar among the residential areas.

In commercial areas (Charbagh, Alambagh, Aminabad, and Chowk) the concentration was in the range of 33.8 to 117.7 µg m^{-3} with an average of 70.4 µg m^{-3} respectively. The average concentration of $PM_{2.5}$ was observed highest at Charbagh among the commercial areas.

In industrial area (Amausi), the average concentration of PM2.5 was 71.1 µg m^{-3}. Among all locations, $PM_{2.5}$ levels were exceeded the prescribed NAAQS of 60 µg m^{-3} except the

3.3. Sulphur Dioxide (SO_2)

In residential area (Aliganj, Vikas Nagar, Indira Nagar and Gomti Nagar), the levels of SO_2 were in the range of 8.7 to 29.2 µg m^{-3} with an average of 16.2 µg m^{-3}. In commercial areas (Charbagh, Alambagh, Aminabad, and Chowk) the concentrations were in the range of 7.9 to 40.8 µg $m^{-3}$with an average of 24.3 µg m^{-3}. In industrial area (Amausi), the mean level was 25.5 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.

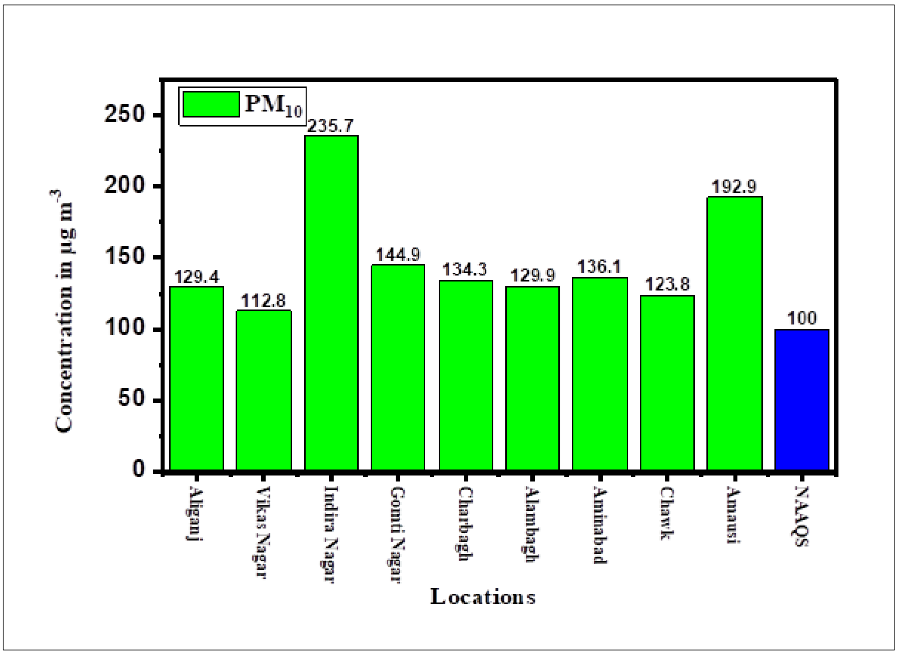
3.4. Nitrogen Dioxide (NO_2)

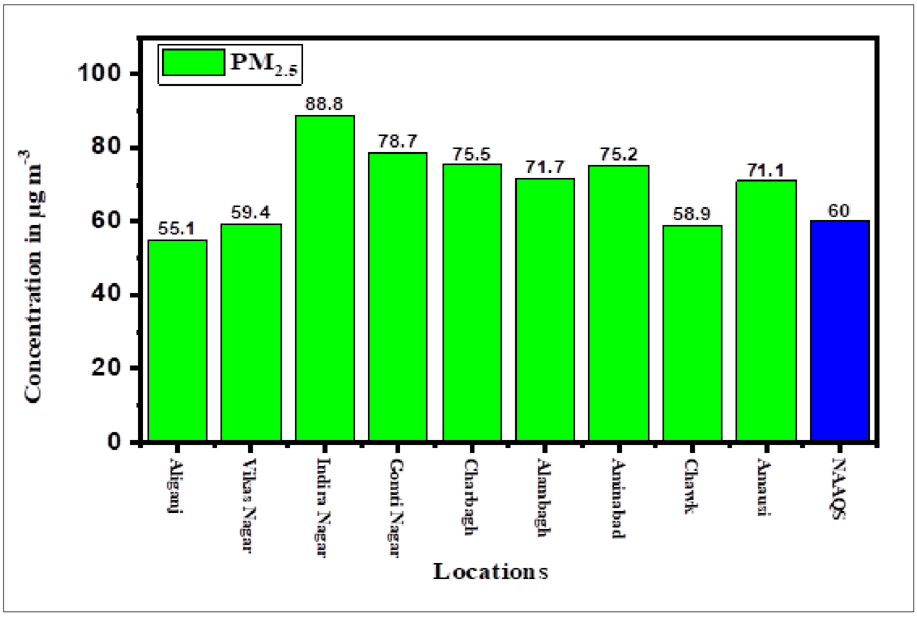
In residential areas (Aliganj, Vikas Nagar, Indira Nagar and Gomti Nagar) the 24 hours concentration of NO_2 was in the range of 9.3 to 59.1 µg m^{-3} with an average of 34.5 µg m^{-3}. In commercial areas (Charbagh, Alambagh, Aminabad, and Chowk) the concentration of NO_2 was in the range of 14.1 to 89.0 µg m^{-3} with an average of 38.8 µg m^{-3}. In industrial areas (Amausi), the average concentration was 47.3 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.

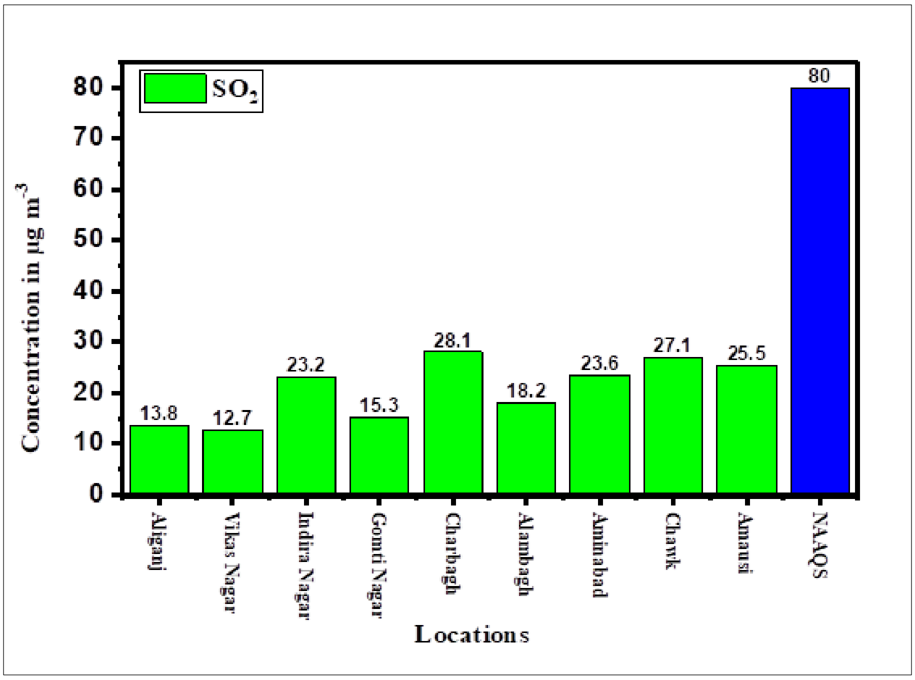
Table 2 Concentration (µg m^{-3}) of PM_{10}, $PM_{2.5}$, SO_2, and NO_2 during Post mansoon 2023

Locations	**PM_{10}**			**$PM_{2.5}$**			**SO_2**			**NO_2**		
Commercial												
	Min.	**Max.**	**Avg.**	**Min.**	**Max.**	**Avg.**	**Min.**	**Max.**	**Avg.**	**Min.**	**Max.**	**Avg.**
Charbagh	71.3	187.5	134.3	51.1	117.7	75.5	18.7	38.8	28.1	16.6	56.6	39.4
Alambagh	100.9	180.7	129.9	38.6	97.1	71.7	13	28.9	18.2	29.4	55.7	41.5
Aminabad	88.5	164.3	136.1	33.8	97.7	75.2	7.9	35.2	23.6	14.1	89	31.2
Chawk	66.4	194.9	123.8	34.4	86.5	58.9	9.2	40.8	27.1	15.7	84.8	43.4
Residential												
Aliganj	102.0	148.4	129.4	45.6	72.6	55.1	9.9	23.8	13.8	19.6	35.4	25.4
Vikas Nagar	58.5	141.5	112.8	34	94.2	59.4	8.7	17.3	12.7	23.6	59.1	37.6

Indira Nagar	111.3	310.9	235.7	66.9	118.4	88.8	17.2	29.2	23.2	19.4	58.6	37.1
Gomti Nagar	101.1	213	144.9	32.5	110.4	78.7	9.2	29.1	15.3	9.3	56.7	38
Industrial												
Amausi	84.3	337.8	192.9	52.9	109.6	71.1	10.6	57.7	25.5	27.4	70.4	47.3
NAAQS 100				60			80		80			







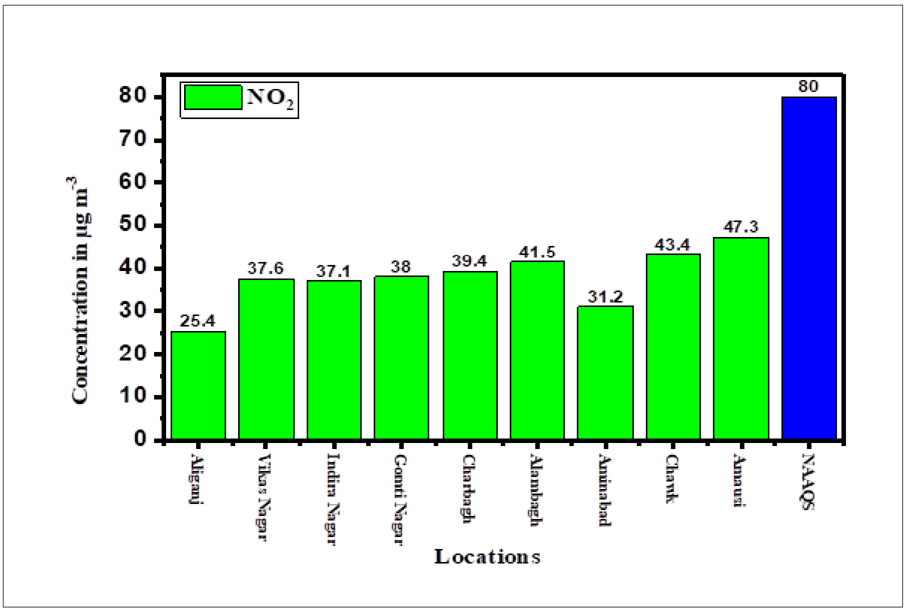


Figure 2 Concentration (µg m^{-3}) PM_{10}, $PM_{2.5}$, SO_2, and NO_2 in different areas of Lucknow city during post-mansoon season 2023 compared with prescribed National Ambient Air Quality Standard (NAAQS)

3.5. Trace Elements

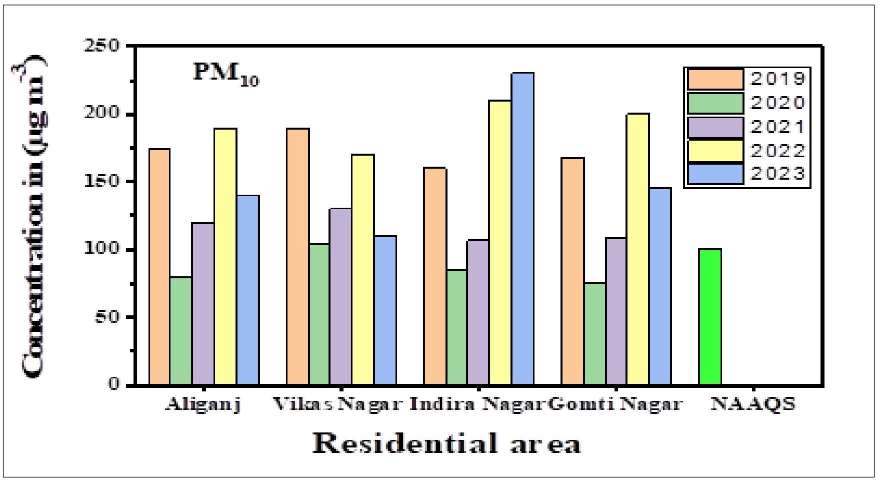
Metal concentration associated with PM_{10} are presented. The average Pb concentration in residential areas was observed 0.0101 µg m^{-3} On the other hand, with an average of 0.0205 µg m^{-3}, the values in commercial areas varied from 0.0028 to 0.037 µg m^{-3}. Pb was found at 0.01 µg m^{-3} in the industrial area of Amausi.

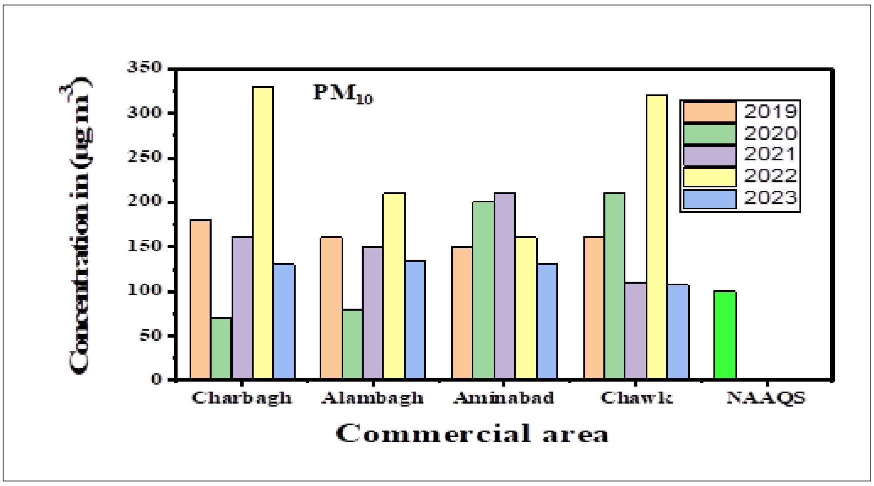
Besides, the concentration of Ni in residential areas ranged between 0.0013 µg m^{-3} (Aliganj) to 0.00897 (Gomti Nagar) µg m^{-3} with an average of 5.08 µg m^{-3}. However, in commercial areas, the values ranged between 0.00319 to 0.01163 µg m^{-3} for Charbagh and Aminabad respectively, with an average of 0.00683 µg m^{-3}. In industrial area Amausi, the value of Ni was found 0.01175 µg m^{-3}.

3.6. Trends of Ambient Air Quality in Lucknow City

To determine the current trend of air pollution in Lucknow city, the measured parameters PM10, PM2.5, SO2, and NO2 for five years following the monsoon have been compared (Figures 3-6). The local environment, urbanisation, and climate are all blamed for minor variations in the readings.

3.6.1. Trend of PM_{10} and $PM_{2.5}$





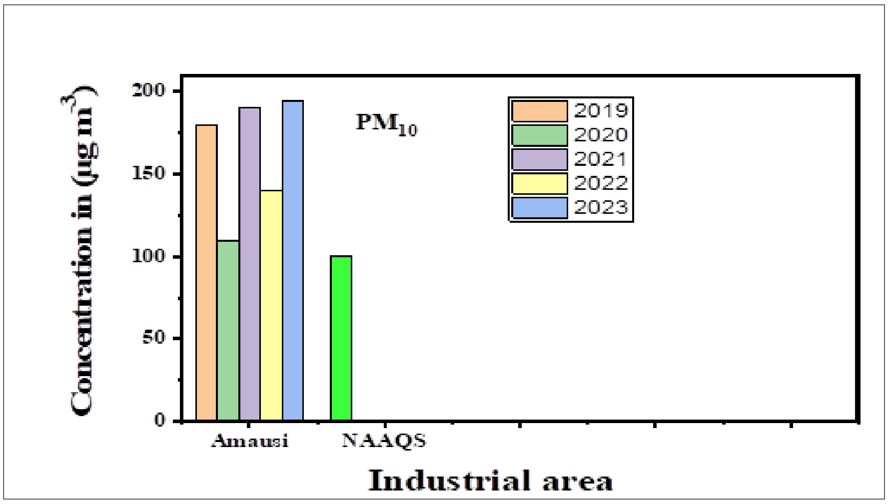


Figure 3 Concentration (µg m^{-3}) of PM_{10} in Lucknow City's residential, commercial, and industrial areas from 2019 to 2023 (post- monsoon), and compared with the recommended NAAQS

Fig. 3 and 4 show that, with the exception of two sites for PM_{10}, namely Indira Nagar and Amausi, the concentrations of $PM_{2.5}$ and PM_{10} are declining until 2020. They then begin to rise from 2021 to 2022 and then decline in 2023. Different parts of the city get sporadic, dispersed rainfall in the post-monsoon season of 2023. When compared to monitoring data from the prior year 2022, the levels of PM_{10} and $PM_{2.5}$ in all residential, commercial, and industrial locations were comparatively lower. While $PM_{2.5}$ concentrations surpassed NAAQS at all sites but not at Aliganj, Vikas Nagar, or Chowk, PM_{10} concentrations exceeded NAAQS standards for all sites.

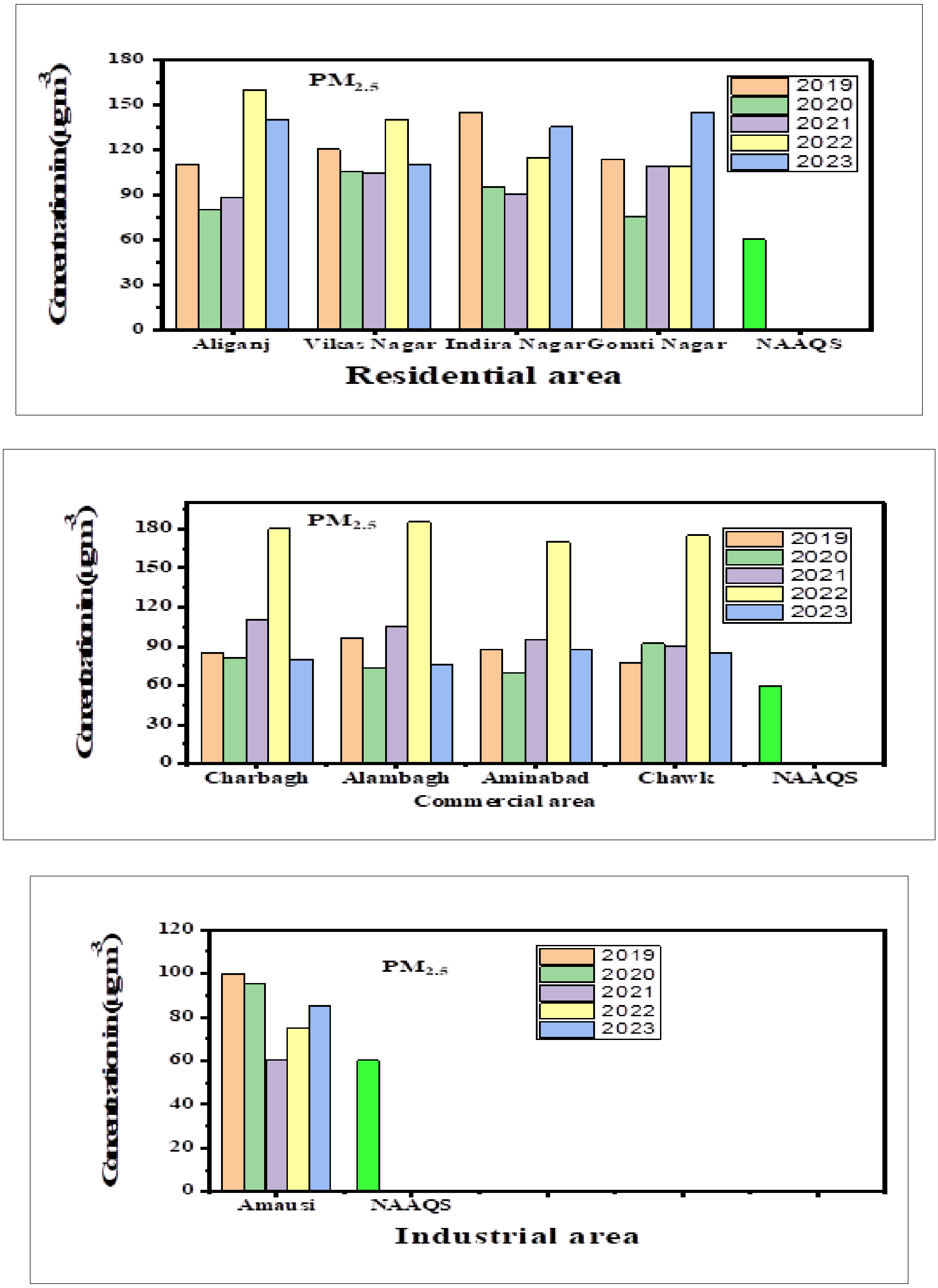


Figure 4 Concentration (µg m^{-3}) of $PM_{2.5}$ in Lucknow City's residential, commercial, and industrial areas from 2019 to 2023 (post- monsoon), and compared with the recommended NAAQS

3.6.2. Trend of SO_2 and NO_2

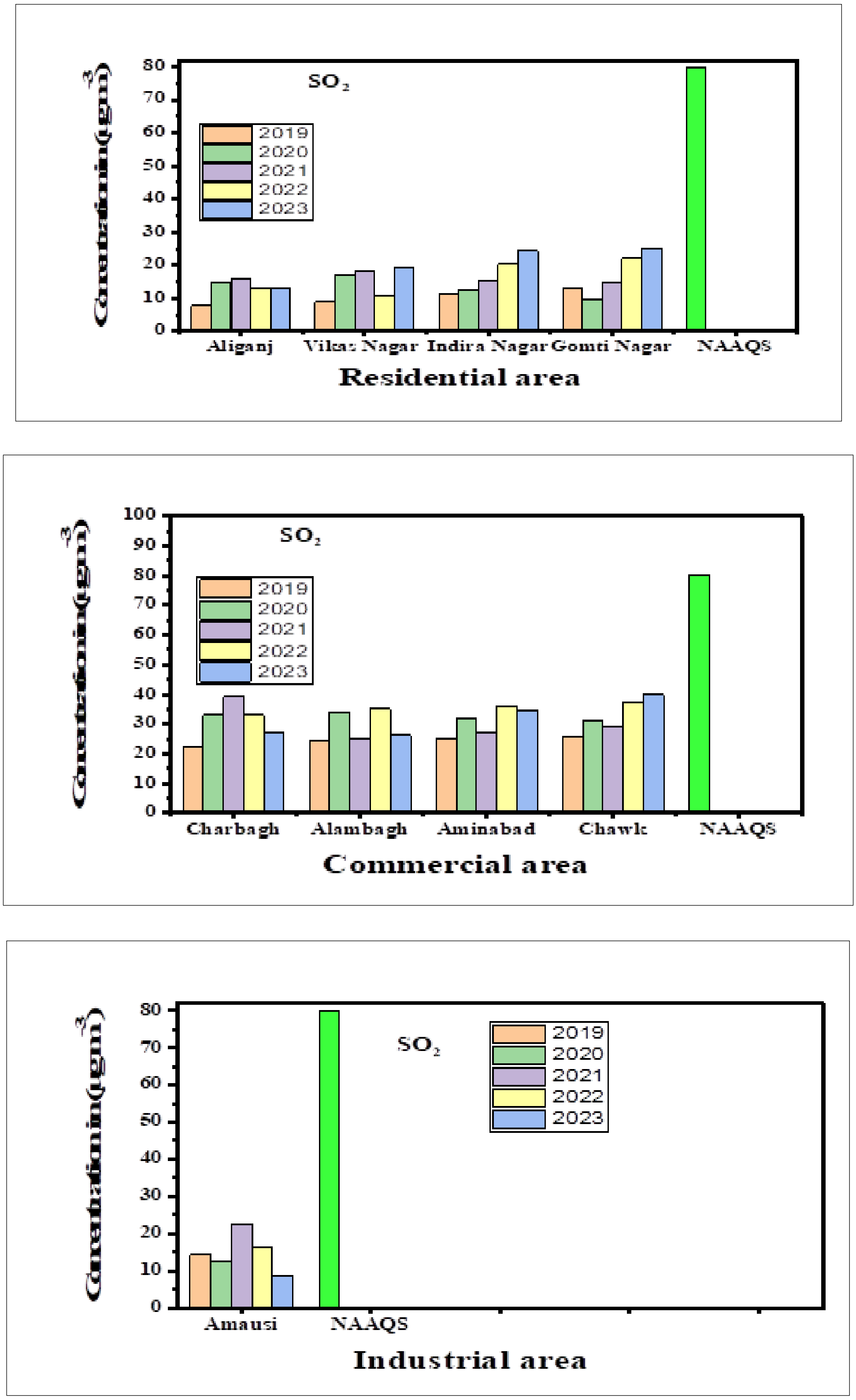


Figure 5 Concentration (µg m^{-3}) of SO_2 in Lucknow City's residential, commercial, and industrial areas from 2019 to 2023 (post- monsoon), and compared with the recommended NAAQS

In Fig. 5 and 6 the post-monsoon SO_2 and NO_2 levels for every location since 2019 are displayed. The trend for SO_2 concentration was downward until 2020, when it began to rise in 2021 and 2022. With the exception of the Amausi site, it declined in 2023. With the exception of the Aliganj site, all test sites show a rise in NO_2 levels from 2022 to 2023. While

NO_2 concentrations were found to have increased from the year 2022, SO_2 concentrations in residential, commercial, and industrial areas were found to have decreased to that of the year 2022. It was discovered that every SO_2 and NO_2 value for the current investigation was below the NAAQS guidelines

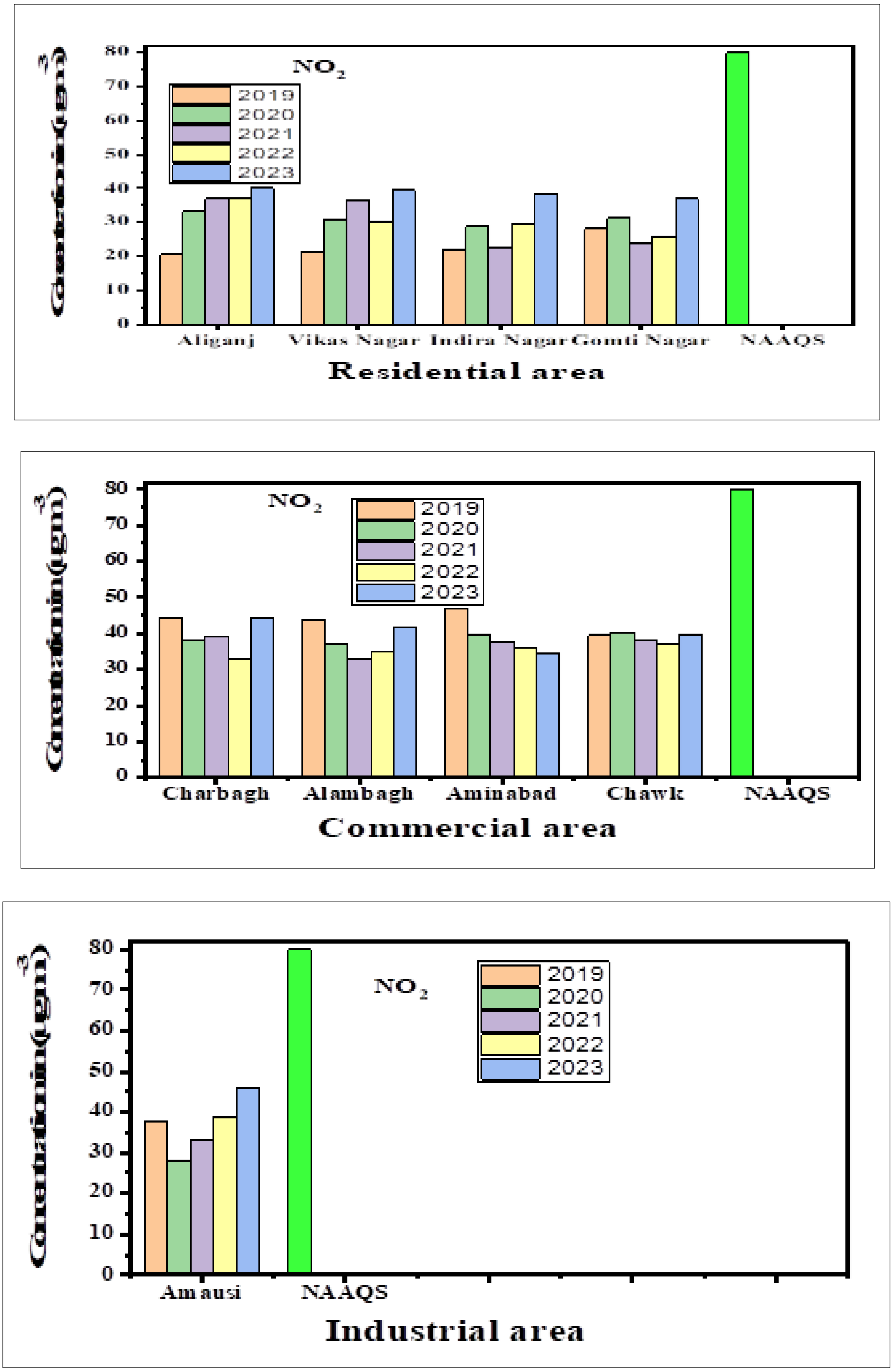


Figure 6 Concentration (µg m^{-3}) of NO_2 in Lucknow City's residential, commercial, and industrial areas from 2019 to 2023 (post- monsoon), and compared with the recommended NAAQS

4. Health Impacts of Air Pollution

The study of the relationship between respiratory illnesses and air pollution have received increased attention from researchers. Studies in toxicology and epidemiology have shown a strong correlation between repairable particles and the prevalence and death rate of human diseases.

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

When inhaled, fine airborne particulate matter with a diameter of less than 2.5 ($PM_{2.5}$) would pass through the larynx. PM2.5 can induce emphysema and bronchitis, aggravate pre-existing heart disease, irritate and erode the alveolar wall, and decrease lung function. It can also enter deeply into the lungs. Particles as small as 0.001 to 0.1 μm in diameter have the ability to enter the lungs deeply and reach the alveolar sacs, which are the sites of gaseous exchange.

4.2. Sulphur Dioxide (SO_2)

Elevated SO_2 can worsen coughing and choking and irritate the throat, nose, and eyes. Exposure to moderate quantities over an extended period of time may result in lung damage, wheezing, and respiratory tract irritation.

4.3. Oxides of Nitrogen (NOx)

Extended exposure to NO2 can impair lung capacity and reduce resistance to infections like influenza and pneumonia. The eyes, nose, throat, and lungs might become irritated by low concentrations of NOx in smog. It may result in nausea, exhaustion, coughing, and shortness of breath.

4.4. Trace Element-Lead (Pb)

Lead is a neurotoxin that impairs children's neurodevelopment and has an impact on the developing fetus's brain.Reduced nerve conduction velocity, anaemia, jaundice, hearing loss, and impaired cognitive and instinctive function in children [24].

4.5. Trace element-Nickel (Ni)

An allergic reaction, persistent bronchitis, decreased lung function, lung cancer, and nasal sinus cancer are among the detrimental health impacts of nickel on humans.Studies on animals have shown that when newborns consume nickel, there is a rise in newborn fatalities and a fall in newborn weight.

5. Strategies for Reducing Air Pollution

- Vehicular emission reduction by permitting only BS-VI complaint and electric, biodiesel, CNG, or hybrid-based vehicles.
- Removal of more than ten years old vehicles from city roads.
- Avoid frequent cutting and digging of roads.
- Reduce resuspension of soil and silt from roads by maintaining road surface and regular vacuum-assisted sweeping and watering of roads.
- Coordinate successive traffic signals to provide for easy crossing traffic and rigorous enforcement of no-parking zones. Encouragement to use public transport for daily commute.
- Installation of more electric vehicle charging stations.
- Plantation along roadsides to absorb air pollutants and enhance scenic beauty.
- Regular fogging on roads with a higher load of pollution in the environment.
- Installation of effective particulate control equipment such as bag filters/scrubbers/ ESPs in the industries.
- Restrict fugitive dust spread from building construction and demolition activities by installing proper HDPE construction nets/meshes.
- Proper covering of trucks carrying garbage/solid wastes/sand/cement/concrete/loose materials etc., avoid overloading.
- Steer clear of burning crop residues in the field. and implementation of in-situ technologies to use/ recycle crop residues.
- Avoid burning of plastic, garbage, trash, and other materials in an open environment.
- Electrical or gas-based crematorium practices shall be encouraged.
- More awareness programs to sensitize public about the clean air practices.
- Restrict haphazard development to avoid hotspots emitting high air pollution.

- To decrease carbon emissions in industries like transportation, manufacturing, agriculture, and production, among others, use energy-efficient equipment.

Nomenclature

SAMP:	State Ambient Monitoring Programme
UPPCB	Uttar Pradesh Pollution Control Board
NAAQS:	National ambient air quality standard
WHO:	World health organisation
NO_2:	Nitrogen dioxide
AQI:	Ambient Air Quality
CPCB:	Central Pollution Control board
PM_{10}:	Particulate matter particle size less than 10 mm
$PM_{2.5}$:	Particulate matter particle size less than 2.5 mm
SO_2:	Sulphur dioxide

6. Conclusions

Due to ongoing flyover (or highway) construction throughout the test period, Indira Nagar has the highest particulate matter levels of any residential area. Due to traffic diversion on surrounding roads and dust entrainment from nearby operations, the activities increased traffic congestion and the density of on-road vehicles. The explanation for Amausi second-highest concentration may have been the ongoing building of flyovers and roadways close to the sampling site, which caused traffic jams and detours. Due to partially unpaved roads and the addition of construction dust to the already high particle load in the surrounding air, these two locations exhibit greater levels of dust entrainment. Alambagh, Amausi, and Chowk recorded the greatest concentrations of SO_2 and NO_2, mostly due to the presence of different business activities and traffic movements in the vicinity of these sampling locations.

According to the overall trend study results, Lucknow's air pollution levels are lower currently than they were in 2022. This might have been caused by the sporadic and dispersed rain that fell over the city throughout the survey. The city saw varying weather conditions on different days, with some days being hot and dry and others windy with rain showers and humid air. This could have caused variations in the concentration of pollutants in the metropolitan area.

Compliance with ethical standards

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Disclosure of conflict of interest

All contributors declare that no relationships of interest occur.

Authors Contributions

Vipin Kumar: Data curation, Investigation, Methodology, Writing – original draft, Writing – review & editing, Supervision, Validation. **Mandvi:** Validation, Visualization, Writing – review & editing, Conceptualization. **Shashank Pandey:** Software investigation. **Vishvanath Pratap Singh:** writing, review & editing.

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