



# Assessment of Air Quality Status of Lucknow City of Year - 2023

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**Abstract :** The study was carried out during the 2023 to see the status of air quality of Lucknow city by monitoring and assessment of some selected air pollutants namely Respirable Particulate Matter (PM<sub>10</sub>), Sulphur dioxide (SO<sub>2</sub>), Nitrogen dioxide (NO<sub>2</sub>) levels, and also AQI of urban Lucknow at 5 representative air pollution monitoring sites located at different locations categories as two residential (Mahanager and Aliganj), two commercial (Hazratganj and Ansal T.C.) and one industrial (Talkatora) areas. The results revealed the 24 hours concentration of PM<sub>10</sub> in the range of 115.58 to 231.87µg/m<sup>3</sup> with an average of 171.26µg/m<sup>3</sup>. The average values of PM<sub>10</sub> irrespective of locations were found to be over permissible limit (PM<sub>10</sub> = 100 µg/m<sup>3</sup>) prescribed by NAAQ and WHO guidelines. Similarly, 24 hours average concentration of SO<sub>2</sub> and NO<sub>2</sub> were found in the range of 6.19 to 11.28µg/m<sup>3</sup> and 15.18 to 43.82µg/m<sup>3</sup> with an average concentration of 8.41µg/m<sup>3</sup> and 24.52µg/m<sup>3</sup> respectively and all the values were below the permissible limits (80µg/m<sup>3</sup>). The 24 hours AQI was recorded in the range of 98 to 187 with an average 141 which was graded unhealthy to severe by NAAQ and WHO throughout the year. The seasonal variations in PM<sub>10</sub>, SO<sub>2</sub> and NO<sub>2</sub> were noticed and found to be maximum 223.65µg/m<sup>3</sup>, 10.96µg/m<sup>3</sup> and 36.02µg/m<sup>3</sup> respectively, in winter and minimum 111.50µg/m<sup>3</sup>, 6.83µg/m<sup>3</sup> and 17.14µg/m<sup>3</sup> respectively, in monsoon season. Similarly seasonal variations in AQI were recorded. It was reported maximum in 182.87 in winter (November - February) and minimum 111 in monsoon (July - October) season.

**Keywords -** PM<sub>10</sub>, SO<sub>2</sub>, NO<sub>2</sub>, Ambient Air Quality (AQI), Lucknow city.

## I. INTRODUCTION

Lucknow is a historical, most populated and largest state capital city of Uttar Pradesh situated near the river Gomati and spread both side of river bank of Gomati. In 18<sup>th</sup> and 19<sup>th</sup> century, it was rolled by Muslim rulers so commonly known as “City of Nawabs”. Like metropolitan cities, air quality of urban Lucknow is also dangerous. Many reports revealed that urban air quality of Lucknow city is deteriorating day by day especially in winter season, mainly due to rapid growth of urbanization, industrialization, transportation and construction activities. (Kumar et. al., 2023; Kumar & Dwivedi, 2021; Akansha et. al., 2017)

Air is natural resources available free of cost. Clean air is the basic needs of every living organism. A healthy adult person required 8 L air per minute for breathing. When air is get polluted, it threaten every living organism (Ghorani-Azam et al., 2016). Air of megacities are being polluted by multiple natural and anthropogenic sources like urbanization, industrialization, rapid growth of human population and increasing number of automobiles on the roads (Satterthwaite et al., 2010). Although pollutants released by these activities are naturally self regulated and absorbed up to a certain extent, and helps in restoring the air quality but when its limits are exceeded, these pollutants are accumulated in the environment and deteriorate air quality. WHO report (2006) data revealed that there are more than 80% of urban populations are exposed to air quality levels above the NAAQ standards and WHO guideline limits (WHO, 2006). However, in recent

studies it has been observed that there are about 90% of world populations living in the unhealthy air quality limits (WHO, 2016). It to be seems, past few decades due to human activities such as industrialization, fossil fuels burning, rapid increase in automobiles number and intensively use of agrochemicals have accelerated the levels of harmful gases like SO<sub>2</sub>, NO<sub>2</sub>, CO, O<sub>3</sub>, and particulate matter (PM) in environment to worrying levels (Wu et al. 2020; Gurjar et al. 2016).

Several workers reported some common components of air pollutants such as PM<sub>2.5</sub>, PM<sub>10</sub>, O<sub>2</sub>, NO<sub>x</sub>, etc are emitted from vehicles used fossil fuels and it accumulated in the environmental air, harming the living organisms in different ways. Recent studies suggested that RSPM in urban areas of Lucknow city above the prescribed standards NAAQ (P100) and WHO guideline. Excess concentration of PM cause many severe detrimental health effects on human. The effects of PM on human health depend on the chemical composition of PM, shape, size, frequency and duration of exposure. Indian standard of ambient air is limited with two specified size of PMs such as PM<sub>2.5</sub> and PM<sub>10</sub>. The elevated levels of these PMs in air causes morbidity and mortality in humans.

Thus it needs of massive camping and awareness programs for common men especially in the urban areas of all metropolitan cities including Lucknow, regarding the air pollution and its consequences on human health. Unlimited growth of human population corresponding to increases number of vehicles for transportation which severely affecting the sustainable development and gradually becoming unbearable

In reference to above facts, the present study has been planned to observe the current status of air quality of Lucknow city and their adverse effects on human health. For this purpose secondary data were collected from 5 representative monitoring sites of different localities of Lucknow city in current year (2023).

### Study location and data collection

Lucknow is largest and most populated city of Uttar Pradesh, located in northern India between 26°85' N latitude and longitude 80°95" E. It is popularly known as the "City of Nawabs". Like other metropolitan cities, the air quality of Lucknow is also found to be poor and unhealthy. According to World Air Quality Report (IQAir, 2019), Lucknow has placed on 11 rank among the top 15 most polluted cities of the world and in an another reports, January, 2019 it was placed on 9 rank in top 10 most polluted cities of the world.

For the assessment of ambient air quality (AQI) in Lucknow city, secondary data has been obtained from the Uttar Pradesh Pollution Control Board (UPPCB), the Central Pollution Control Board (CPCB), and the Centre or Science and Environment (CSE). The assessment of the monthly average concentration of ambient air pollution in Lucknow has been conducted with the recorded data (from Annual Report UPPCB, 2023) against 5 monitoring stations are 2 residential (Mahanager and Aliganj), 2 commercial (Hazratganj and Ansal T) and 1 industrial (Talkators) area for each month and comparing the average value with the given NAAO standards. Seasonal variations in AQI and its three representative components such as PM<sub>10</sub>, SO<sub>2</sub>; and NO<sub>2</sub>, were also recorded.

### Source of air pollution in Lucknow

Multiple factors are responsible for causing air pollution in Lucknow city, among them transportation is the main factor, where use of large number of poorly-maintained diesel and petrol vehicles and poor traffic controlling management makes it major contributor in air pollution. Additionally it, there are several large, medium and small-scale industries situated in 04 designated Industrial sites in and around Lucknow city named, Talkatora Udyog Asthan, Amausi, Chinhath and Sarojini Nagar industrial areas, and about 255 operational brick kiln situated around city also contribute in air pollution.

Presently, Lucknow included in Smart City Yojana results a huge ongoing construction activities viz., roads fly over construction, metro rail construction, and multistory apartment construction have also been contributing to the sit pollution. Besides these, several others domestic, industrial and commercial activities, urbanization, deforestation, population growth and energy consumption are major driving force of air pollution Lucknow. Thus the major causes of air pollution in Lucknow city em be attributed to emissions from transportation, diesel generators, industrial, domestic and constriction activities, burning of biomass, municipal solid or waste and garbage, crop residue and resuspension of road dust.

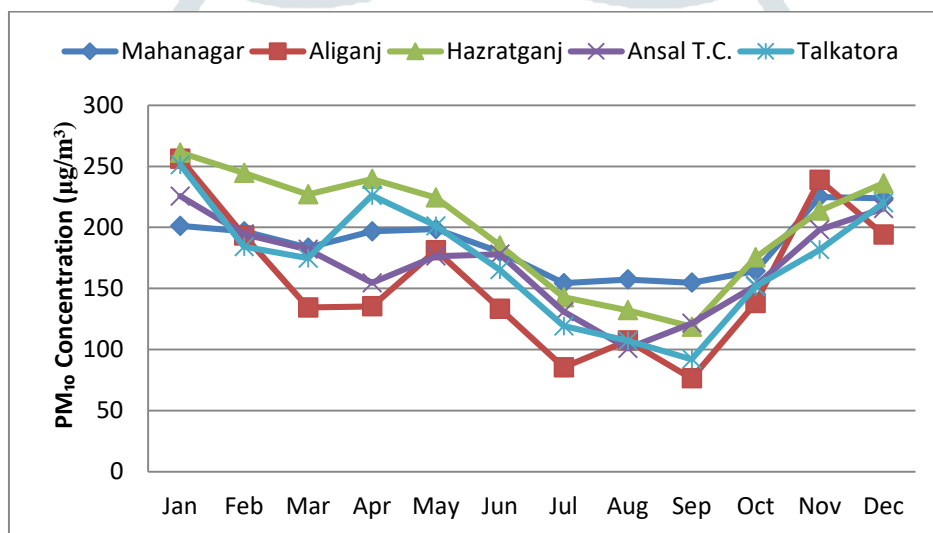
## II. DATA ANALYSIS AND RESULTS

### Respirable Suspended Particulate Matter (RSPM or PM)

The 24 hours mean concentration of PM was observed in Mahanagar, Aliganj, Hazratganj, Ansal T.C. and Talkatora were 186.36, 156.17, 200.09, 169.18 and 172.91µg/m<sup>3</sup>, respectively. It was recorded maximum 200.09µg/m<sup>3</sup> in Hazaratganj (commercial area) and minimum 156.17µg/m<sup>3</sup> in Aliganj. (Residential area) (Table-1, Fig. 1)

**Table-1** Monthly average concentrations of PM<sub>10</sub> (µg/m<sup>3</sup>) in different localities of Lucknow city (2023)

Locations	Type	Months												Average
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Mahanagar	R	201.27	196.83	183.43	196.76	198.56	179.94	154.40	157.39	154.76	164.28	224.97	223.81	186.36
Aliganj	R	256.25	193.32	134.39	135.37	181.26	133.36	85.39	107.27	76.40	138.10	238.77	194.16	156.17
Hazratganj	C	261.19	244.61	226.98	239.67	224.48	185.23	142.83	132.25	118.77	175.38	213.73	236.05	200.09
Ansal T.C.	C	225.61	194.55	181.92	154.54	176.46	178.02	131.08	100.87	121.41	152.23	198.09	215.38	169.18
Talkatora	I	251.28	184.25	174.84	226.17	201.27	165.28	119.23	107.12	92.09	151.74	181.73	220.03	172.91
Average		239.12	202.71	180.31	190.50	196.40	168.36	126.93	120.98	112.68	156.34	211.45	217.88	176.94



**Figure-1** Monthly variation of PM<sub>10</sub> concentrations in different localities of Lucknow city

In residential areas (Mahanagar and Aliganj), the 24 hours average concentrations of PM<sub>10</sub> were in the range of 115.58 to 231.87µg/m<sup>3</sup> with an average of 171.26µg/m<sup>3</sup>. In commercial areas (Hazratganj and Ansal TC.) the average concentrations of PM<sub>10</sub> were in the range of 116.56 to 243.40µg/m<sup>3</sup> with an average of 184.88µg/m<sup>3</sup> respectively. In industrial area (Talkatora) the average concentrations of PM were in the range of 92.09 to 251.28µg/m<sup>3</sup> with an average of 172.91µg/m<sup>3</sup> (Table-2).

The seasonal variations in PM concentrations were also recorded in residential, commercial and industrial areas. In residential area 24 hours average concentrations of PM<sub>10</sub> was observed 167.88, 129.79, and 216.17 µg/m<sup>3</sup> in summer (March-June), monsoon (July - October) and winter (November-December), respectively. Similarly in commercial areas PM<sub>10</sub> was recorded 195.91, 134.35 and 223.65µg/m<sup>3</sup>; and in industrial area 191.89, 117.54 and 209.32 µg/m<sup>3</sup> in summer, monsoon and winter, respectively.

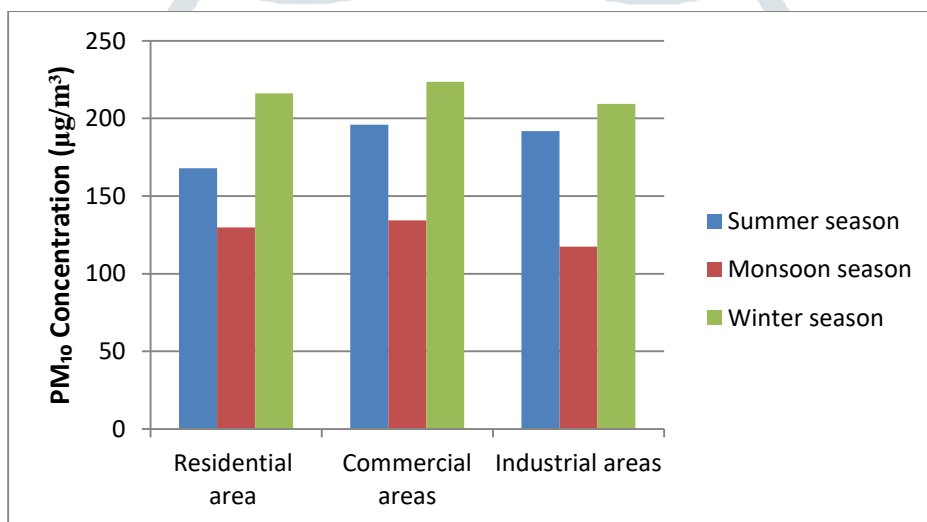
**Table- 2** Monthly variations of PM (µg/m<sup>3</sup>) concentrations in residential, commercial and industrial areas of Lucknow city.

Locations Type	Months												Average
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Residential area (R)	228.76	195.07	158.91	166.06	189.91	156.65	119.89	132.33	115.58	151.19	231.87	208.98	171.26
Commercial areas(C)	243.40	219.58	204.45	197.10	200.47	181.62	136.95	116.56	120.09	163.80	205.91	225.71	184.88

Industrial areas(I)	251.28	184.25	174.84	226.17	201.27	165.28	119.23	107.12	92.09	151.74	181.73	220.03	172.91
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**Table-3** Seasonal Variations of PM<sub>10</sub> (µg/m<sup>3</sup>) concentration in residential, commercial and industrial areas of lucknow city

Locality Type	Summer season (March - June)	Monsoon season (July - October)	Winter season (November-February)
Residential area (R)	167.88	129.79	216.17
Commercial areas(C)	195.91	134.35	223.65
Industrial areas(I)	191.89	117.54	209.32



**Figure- 2** Seasonal variations of PM<sub>10</sub> concentration in residential, commercial and industrial areas of Lucknow city.

The maximum concentration of PM<sub>10</sub> was recorded 223.65µg/m<sup>3</sup> in winter in commercial area and was minimum 111.50µg/m<sup>3</sup> in monsoon in industrial area. (Table-3, Figure-2)

All the values of PM were recorded above the prescribed NAAQ Standard of 100µg/m<sup>3</sup>, except residential area (Aliganj) in month of July and September. It was recorded 85.39 and 76.40µg/m<sup>3</sup> and in Industrial area (Talkatora) in month of September. It was recorded 92.09µg/m<sup>3</sup>. (Table-1)

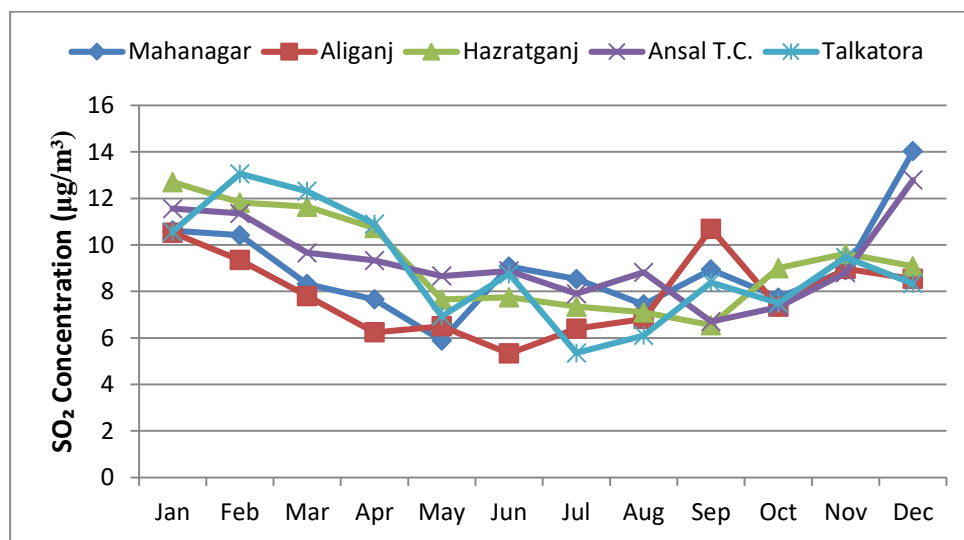
**Sulphur dioxide (SO<sub>2</sub>)**

The 24 hours mean concentration of SO<sub>2</sub>, was observed in Mahanagar, Aliganj. Hazratganj. Ansal T.C. and Talkatora were 8.96, 7.87, 9.24, 9.31 and 8.97µg/m<sup>3</sup>, respectively. It was recorded maximum 9.31µg/m<sup>3</sup> in Ansal T.C. (commercial area) and minimum 7.87µg/m<sup>3</sup> in Aliganj. (Residential area) (Table-4, Fig. 3)

**Table- 4** Monthly average concentrations of SO<sub>2</sub> (µg/m<sup>3</sup>) in different localities of Lucknow city. (2023)

Locations	Type	Months												Average
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Mahanagar	R	10.62	10.42	8.32	7.66	5.89	9.07	8.53	7.44	8.94	7.73	8.91	14.03	8.96

Aliganj	R	10.53	9.35	7.80	6.24	6.50	5.33	6.40	6.82	10.69	7.34	8.97	8.54	7.87
Hazratganj	C	12.70	11.82	11.64	10.73	7.65	7.75	7.35	7.10	6.55	9.00	9.62	9.08	9.24
Ansal T.C.	C	11.56	11.35	9.66	9.33	8.66	8.88	7.90	8.82	6.70	7.33	8.80	12.79	9.31
Talkatora	I	10.57	13.06	12.31	10.90	6.93	8.75	5.35	6.10	8.39	7.50	9.47	8.33	8.97
Average		11.19	11.2	9.94	8.97	7.12	7.95	7.10	7.25	8.25	7.78	9.15	10.55	8.87



**Figure-3** Monthly variations of SO<sub>2</sub> concentrations in different localities of Lucknow city

In residential areas (Mahanagar and Aliganj) the 24 hours average concentrations of SO<sub>2</sub> were in the range of 6.19 to 11.28µg/m<sup>3</sup> with an average of 8.41µg/m<sup>3</sup>. In commercial areas (Hazratganj and Ansal T.C.) the average concentrations of SO<sub>2</sub> were in the range of 6.62 to 12.13µg/m<sup>3</sup> with an average of 9.27µg/m<sup>3</sup> respectively. In area (Talkatora) concentrations of SO<sub>2</sub> were in the range of 6.10 to 13.06µg/m<sup>3</sup> with an average of 8.97µg/m<sup>3</sup> (Table-5).

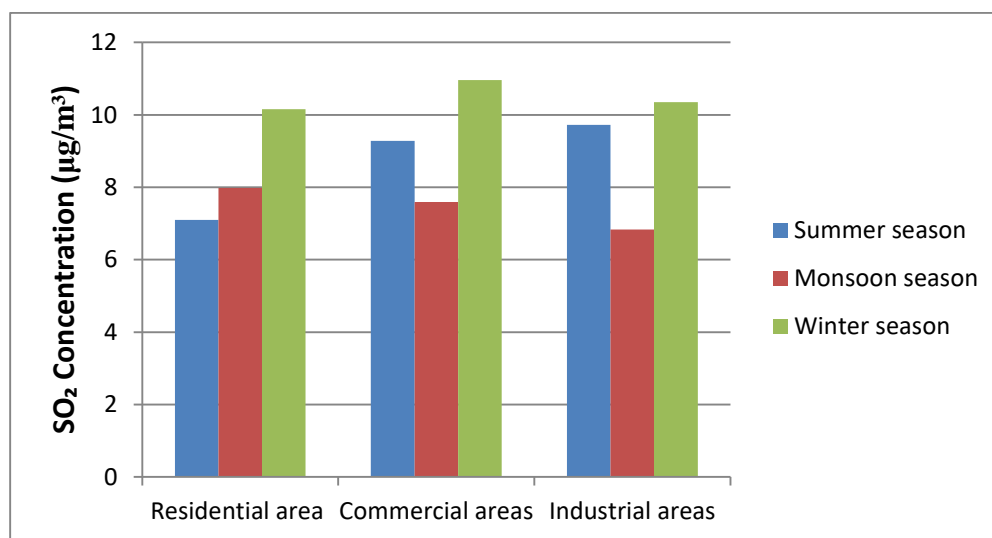
The seasonal variations in SO<sub>2</sub> concentrations were also recorded in residential, commercial and industrial areas. In residential area 24 hours average concentrations of SO<sub>2</sub> was observed 7.1, 7.98 and 10.16 µg/m<sup>3</sup> in summer (March - June), (July - October) and winter (November-December) respectively. Similarly in commercial areas SO was recorded 9.28, 7.59 and 10.96 µg/m<sup>3</sup>, and in industrial area 9.72, 6.83 and 10.35 µg/m<sup>3</sup> in summer, monsoon and winter, respectively (Table-6.)

**Table-5** Monthly variations of SO<sub>2</sub> (µg/m<sup>3</sup>) concentrations in residential, commercial and industrial areas of Lucknow city (2023)

Locations Type	Months												Average
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Residential area (R)	10.57	9.88	8.06	6.95	6.19	7.20	7.46	7.13	9.81	7.53	8.94	11.28	8.41
Commercial areas(C)	12.13	11.58	10.65	10.03	8.15	8.31	7.62	7.96	6.62	8.16	9.21	10.93	9.27
Industrial areas(I)	10.57	13.06	12.31	10.90	6.93	8.75	5.35	6.10	8.39	7.50	9.47	8.33	8.97

**Table-6** Seasonal variations of SO<sub>2</sub> (µg/m<sup>3</sup>) concentrations in residential, commercial and industrial areas of Lucknow city

Locality Type	Summer season (March - June)	Monsoon season (July - October)	Winter season (November-February)
Residential area (R)	7.1	7.98	10.16
Commercial areas(C)	9.28	7.59	10.96
Industrial areas(I)	9.72	6.83	10.35



**Figure-4** Seasonal variations of SO<sub>2</sub>, concentrations in residential, commercial and industrial areas of Lucknow city

The maximum concentration of SO<sub>2</sub> was recorded 10.96µg/m<sup>3</sup> in winter in commercial area and was minimum 6.83µg/m<sup>3</sup> in monsoon in industrial area (Table-6, Fig-4).

All the values of SO<sub>2</sub> were recorded below the prescribed NAAQ Standard (80 µg/m<sup>3</sup>) and WHO guidelines (20 µg/m<sup>3</sup>).

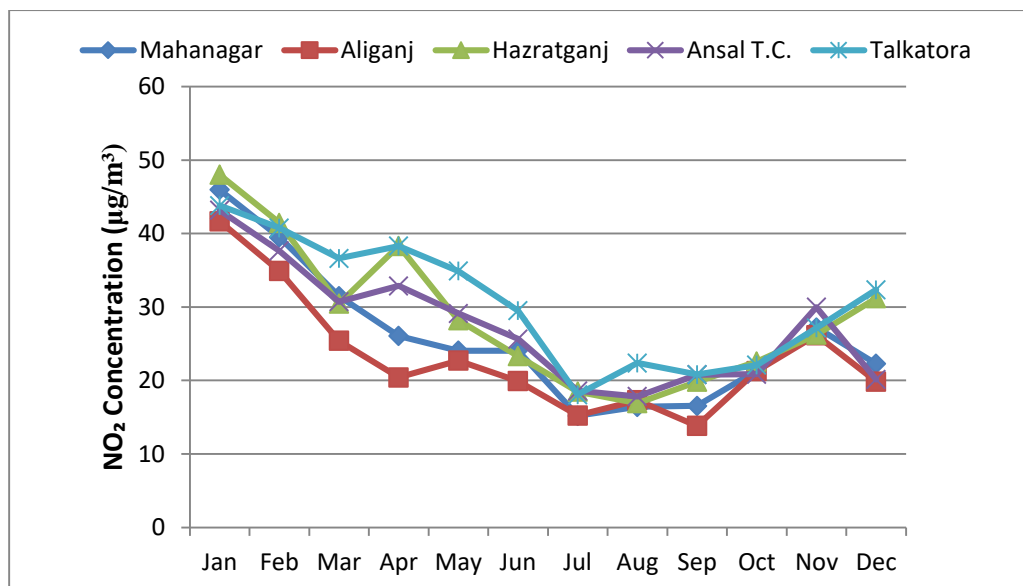
#### Oxides of Nitrogen (NO<sub>x</sub>)

The 24 hours mean concentration of NO: was observed in Mahanagar, Aliganj, Hazratganj, Ansal T.C. and Talkatora were 25.84, 23.22, 28.75, 27.28 and 30.51µg/m<sup>3</sup>, respectively. It was recorded maximum 30.51µg/m<sup>3</sup> in Talkatora (industrial area) and minimum 23.22 µg/m<sup>3</sup> Aliganj (residential area) Table-7, Fig. 5)

**Table-7** Monthly average concentrations of NO<sub>2</sub> (µg/m<sup>3</sup>) in different localities of Lucknow city (2023)

Locations	Type	Months												Average
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Mahanagar	R	45.97	39.49	31.49	26.05	24.06	24.06	15.20	16.42	16.54	21.34	27.21	22.27	25.84
Aliganj	R	41.67	34.90	25.40	20.43	22.70	19.91	15.23	17.30	13.83	21.29	26.16	19.85	23.22
Hazratganj	C	48.01	41.46	30.46	38.31	28.21	23.31	18.49	16.92	19.84	22.58	26.23	31.19	28.75
Ansal T.C.	C	43.18	37.64	30.72	32.87	29.14	25.64	18.59	17.82	20.80	20.86	29.98	20.13	27.28
Talkatora	I	43.81	40.76	36.62	38.29	34.91	29.51	18.06	22.37	20.82	22.10	27.15	32.36	30.51
Average		44.52	38.85	30.93	31.19	24.06	24.48	17.11	18.16	18.36	21.63	27.34	25.16	27.12





**Figure-5** Monthly variations of NO<sub>2</sub> concentrations in different localities of Lucknow city

In residential areas (Mahanagar and Aliganj) the 24 hours average concentrations of NO<sub>2</sub> were in the range of 15.18 to 43.82 µg/m<sup>3</sup> with an average of 24.52 µg/m<sup>3</sup>. In commercial areas (Hazratganj and Ansal T.C.) the average concentrations of NO<sub>2</sub> were in the range of 17.37 to 45.59 µg/m<sup>3</sup> with an average of 28.01 µg/m<sup>3</sup> respectively. In area (Talkatora) concentrations of NO<sub>2</sub> were in the range of 18.06 to 43.81 µg/m<sup>3</sup> with an average of 30.56 µg/m<sup>3</sup> (Table-8).

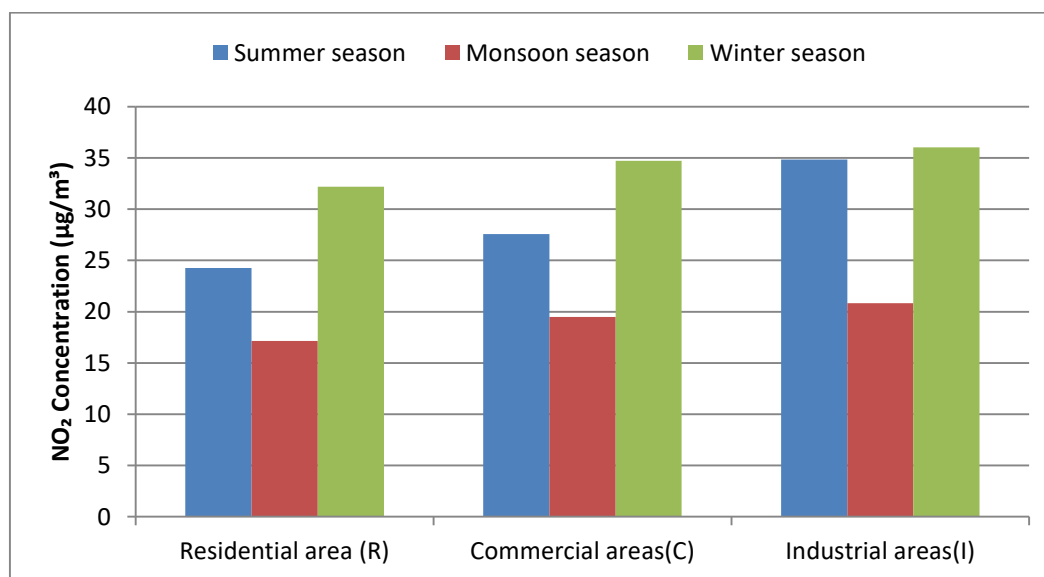
The seasonal variations in NO<sub>2</sub> concentrations were also recorded in residential, commercial and industrial areas. In residential area 24 hours' average concentrations of NO<sub>2</sub> was observed 24.26, 17.14 and 32.18 µg/m<sup>3</sup> in summer (March-June), monsoon (July-October) and winter (November-December), respectively. Similarly in commercial areas NO<sub>2</sub> was recorded 27.57, 19.48 and 34.72 µg/m<sup>3</sup>; and in industrial area 34.83, 20.83 and 36.02 µg/m<sup>3</sup> in summer, monsoon and winter, respectively (Table-9).

**Table-8** Monthly variations of NO<sub>2</sub> (µg/m<sup>3</sup>) concentrations in residential, commercial and industrial areas of Lucknow city

Locations Type	Months												Average
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Residential area (R)	43.82	37.19	28.44	23.24	23.38	21.98	15.21	16.86	15.18	21.31	26.68	21.06	24.52
Commercial areas(C)	45.59	39.55	30.59	35.59	28.67	24.47	18.54	17.37	20.32	21.72	28.10	25.66	28.01
Industrial areas(I)	43.81	40.76	36.62	38.29	34.91	29.51	18.06	22.37	20.82	22.10	27.15	32.36	30.56

**Table-9** Seasonal variations of NO<sub>2</sub> (µg/m<sup>3</sup>) concentrations in residential, commercial and industrial areas of Lucknow city

Locality Type	Summer season (March - June)	Monsoon season (July - October)	Winter season (November-February)
Residential area (R)	24.26	17.14	32.18
Commercial areas(C)	27.57	19.48	34.72
Industrial areas(I)	34.83	20.83	36.02

**Figure-6** Seasonal variations of NO<sub>2</sub> concentrations in residential, commercial and industrial areas of Lucknow city.

The maximum concentration of NO<sub>2</sub> was recorded 36.02µg/m<sup>3</sup> in winter in industrial area and was minimum 17.14µg/m<sup>3</sup> in monsoon in residential area (Table-9, Fig.9).

All the values of NO were recorded below the prescribed NAAQ Standard of 80µg/m<sup>3</sup>.

### Ambient Air Quality (AQI)

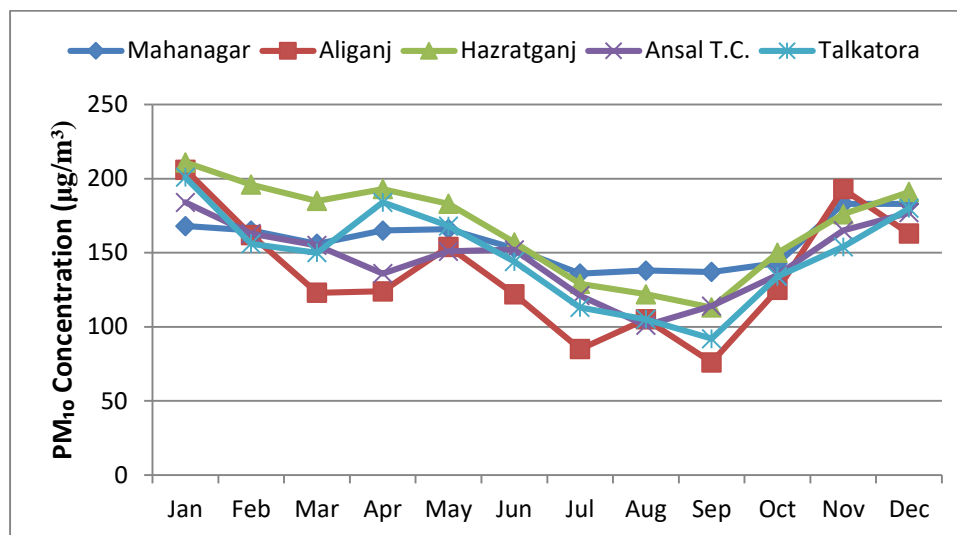
The 24 hours mean level of AQI was observed in Mahanagar, Aliganj, Hazratganj, Ansal T.C. and Talkatora were 157.75, 136.5, 167.16, 146.16 and 148.41, respectively. It was recorded maximum 167.16 in Hazratganj (commercial area) and minimum 136.5 in Aliganj (residential area) (Table-10, Fig. 7).

**Table-10** Monthly Average of ambient air quality (AQI) in Lucknow city (2023)

Locations	Type	Months												Average
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Mahanagar	R	168	165	156	165	166	153	136	138	137	143	183	183	157.75
Aliganj	R	206	162	123	124	154	122	85	105	76	125	193	163	136.5
Hazratganj	C	211	196	185	193	183	157	129	122	113	150	176	191	167.16
Ansal T.C.	C	184	163	155	136	151	152	121	101	114	135	165	177	146.16



Talkatora	I	201	156	150	184	168	144	113	105	92	134	154	180	148.41
Average		194	168.4	153.8	160.4	164.4	145.6	116.8	114.2	106.4	137.4	174.2	178.8	151.19



**Figure-7** Monthly variation of AQI in different localities of Lucknow city.

In residential areas (Mahanagar and Aliganj), the 24 hours average levels of AQI were in the range of 98 to 187 with an average of 141. In commercial areas (Hazratganj and Ansal TC) the average levels of AQI were in the range of 128.5 to 197.5 with an average of 164, respectively. In industrial area (Talkatora) the average levels of AQI were in the range of 78 to 201 with an average of 143 (Table-11)

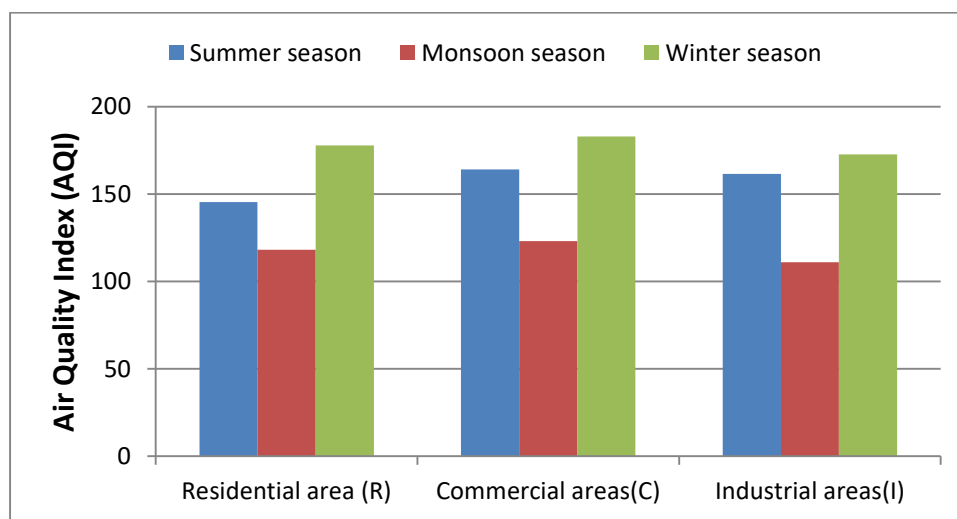
**Table-11** Monthly variations in AQI in residential, commercial and industrial areas of Lucknow city.

Locations Type	Months												Average
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Residential area (R)	187	163.5	139.5	144.5	160	137.5	110.5	121.5	106.5	134	188	173	147.12
Commercial areas(C)	197.5	179.5	170	164.5	167	154.5	125	111.5	113.5	142.5	170.5	184	156.66
Industrial areas(I)	201	156	150	184	168	144	113	105	92	134	154	180	148.41

The seasonal variations in AQI levels were also recorded in residential, commercial and industrial areas. In residential area 24 hours average level of AQI was observed 145.37, 118.12 and 177.87 in summer (March - June), monsoon (July - October) and winter (November - December), respectively. Similarly in commercial areas AQI was recorded 164, 123.12 and 182.87, and in industrial area 161.5, 111 and 172.75 in summer, monsoon and winter, respectively (Table-12, Fig.8)

**Table-12** Seasonal variations in AQI in residential, commercial and industrial areas of Lucknow city.

Locality Type	Summer season (March - June)	Monsoon season (July - October)	Winter season (November-February)
Residential area (R)	145.37	118.12	177.87
Commercial areas(C)	164	123.12	182.87
Industrial areas(I)	161.5	111	172.75

**Figure-8** Seasonal variations in AQI in residential, commercial and industrial areas of Lucknow City (2023)

The maximum levels of AQI was recorded 182.87 in winter in commercial area and was minimum 111 in monsoon in industrial area (Table-12)

All the values of AQI were recorded above the prescribed NAAQ Standards (0-50).

### III.DISCUSSION

In developing countries, India has fastest growing economy and comes in 5<sup>th</sup> place among the developing countries after China. Therefore all Indian megacities and towns rapidly involved in infrastructure development, construction activities, urbanization, and industrialization. Besides these, introduction and establishment of several small, medium and large industries in or around the metropolitan cities are also responsible for air pollution. Harmful and uncontrolled emissions of these industries are severely affecting the air quality. Almost all cities of India are having higher concentrations of Respirable Suspended Particulate Matter (PM<sub>10</sub>) than the prescribed limits of NAAQS and WHO guidelines. Several workers have been earlier reported higher concentrations of PM<sub>10</sub> in air of Indian megacities such as in Delhi (Trivedi et al., 2014), Kolkata (Das et al., 2015), Raipur (Girri et al., 2013), Kanpur (Singh and Gupta, 2015) and Lucknow (Lawrence & Fatima, 2014; Saini et al., 2022)

In present investigation higher concentration of PM in Lucknow city were recorded in throughout year (2023), which is above than the prescribed standards NAAQS and WHO guidelines. It may be attributed due to undergo rapid industrialization, urbanization and various constructive activities like construction of flyovers, roads, highways, multi storey apartments and shopping malls are develop within or around the Lucknow city. Various scientific reports suggested that the almost all developed countries, such as the U.S., France, Britain, Germany etc. have already passed this phase (Yang et al., 2018). The increased concentrations of PM in megacities can be attributed to increasing vehicular exhaust, construction, transportation, increasing fossil fuel use by power-heavy industries and biomass combustion (Saini et al., 2022; Lin et al., 2018, Pant et al., 2016 and Guttikunda et al., 2014). Urban areas of Lucknow city also shows significant seasonal variations in PM concentrations, it was reported maximum in winter and minimum in monsoon. The higher concentration of

PM<sub>10</sub> reported in present study in winter coincide with emissions from fossil fuel, burning of agricultural climatic conditions and biomass burning for heating in winter (Yang et al., 2017; He et al., 2017 and Deka & Hoque, 2014). The adverse climatic conditions in winter like high humidity, slow winds and lower boundary layer height may also promote the accumulation of PM pollutants in air (Massey et al., 2012). In monsoon season PM concentrations were reported minimum, which can be attributed due to the rainfall most of the PM wash off from the air and settle down in ground (Ganguly et al., 2015, Saini et al., 2022). The other possible reason may be significant decline PM concentrations in monsoon season due to suspension of construction activity in this period. The average annual concentrations of PM<sub>10</sub> reported highest in commercial areas and lowest in residential area. In previous studies it was recorded maximum in industrial areas followed by commercial and residential areas. The increased PM<sub>10</sub> in commercial areas attributed due to extra vehicular activities and poor traffic controlling system (Mumtaz et al., 2017). However, decreased PM concentration in industrial areas shown more focus of pollution controlling authorities on these areas. The similar observations and suggestions have been given by Saini et al. (2022).

Rapid industrial development and urbanization are responsible for elevation of PM<sub>10</sub> emission. Exposure of PMs (PM<sub>10</sub> and PM<sub>2.5</sub>) pollution has been associated with increased risks of cardiovascular, lungs and cerebro-vascular diseases (Laden et al, 2006; Pope et al., 2009 and Pope et al., 2011). According to the World Health Organization (WHO), air pollution is 92% global burden of diseases of the world's population, currently about 3 million annual deaths were reported over the world where the level air quality exceeds from the WHO guideline (W.H.O., 2016). Cohen et al. (2005) were reported the higher concentration of PM causes 8 million premature death and 6.4 million people last their life per year over the world.

The decreased SO<sub>2</sub> and NO<sub>2</sub> concentrations from the prescribed standards values (60 µg/m<sup>3</sup>) of NAAQ and WHO guidelines were observed in present study is similar to the observations of Mumtaz et al., (2017) and Saini et al., (2022). They were earlier reported similar observations in Lucknow city. The monthly average concentration of SO<sub>2</sub> and NO<sub>2</sub> were found maximum in February and January, respectively, whereas minimum in July for both SO<sub>2</sub> as well as NO<sub>2</sub> respectively. In case of seasonal variations concentration of SO<sub>2</sub> and NO<sub>2</sub>, were reported maximum in winter season in industrial area and minimum in monsoon season in residential area. The present findings were found to be similar to Saini et al., (2022). They were reported maximum concentration of SO<sub>2</sub> and NO, in industrial areas during winter and minimum in residential areas during monsoon. The average increase of SO<sub>2</sub> and NO<sub>2</sub> in winter may be associated due to excessive burning of fossil fuels like coal and oil in industries, traffic congestion, burning of agricultural residues, burning of biomass for heating houses to prevent cooling and uncontrolled use firecrackers in celebration of New Year and festivals like Dashhara and Diwali. Besides, these meteorological conditions during winter also help in accumulation of pollutants in the environment. The minimum concentration of SO<sub>2</sub> and NO<sub>2</sub> were reported in monsoon period may be attributed due to rainfall which washout pollutants from air. Similar observations and findings were earlier reported by Mumtaz et al., (2017) and Saini et al., (2022).

#### IV. CONCLUSION

This study carried out to assess the current status of air quality of Lucknow city. For this purpose secondary data were collected from Uttar Pradesh Pollution Control Board website and analyzed monthly and seasonally variations in PM<sub>10</sub>, SO<sub>2</sub> and NO<sub>2</sub> of 5 representative locations. Study results revealed there is a higher concentration of PM<sub>10</sub> occurs throughout year from the prescribed NAAQ Standards and WHO guidelines but it was less than the previous years. Its peak concentration was reported in month of January, 2023 in winter and minimum in month of September, 2023. Concentration of SO<sub>2</sub>, and NO<sub>2</sub>; were observed below the prescribed levels in every month in study year. In monsoon season concentration of both SO<sub>2</sub>, and NO<sub>2</sub> was found to be lower than the summer and winter

Although the great efforts carried out by state and central pollution control heard to slowing down pollution which results concentration of SO<sub>2</sub>, and NO<sub>2</sub> become reduce from prescribed NAAQ Standard but problem related to PM<sub>10</sub> is remain still constant and it was found above the prescribed limits throughout year in Lucknow city, which is great matter of concern. Thus it needs massive camping and awareness programme for common people in megacities by pollution control board authorities in association with social welfare groups and educational institutions.

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