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# Ambient Air Quality Status of Ayodhya City, Uttar Pradesh, India

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**ABSTRACT**

Air pollution has become global concern due to its effect and consequences caused by continues urbanization and industrialization. The air quality parameters of nitrogen dioxide ($NO_2$), sulfur dioxide ($SO_2$), and $PM_{10}$ at Naka Bypass (S-1), and Hanuman Garhi Chauraha Ayodhya (S-2) in Ayodhya city has been monitored for 2 consecutive years (2019 to 2021). The concentrations of $SO_2$ and $NO_2$ at both the sites were found within the CPCB's prescribed standards. The highest value of 8.71 µg/m$^3$ and 9.35 µg/m$^3$ was observed for $SO_2$ during December (2019 and 2020) respectively, whereas lowest concentration 4.33 µg/m$^3$ and 4.73 µg/m$^3$ was observed during May (2020 & 2021) respectively at S-1. Highest observed $NO_2$ value was 28.59 µg/m$^3$ and 27.69 µg/m$^3$ during the month of December (2019 & 2020) respectively, while the minimum observed value was 13.25 µg/m$^3$ and 14.4 µg/m$^3$ during the month of August 2020 and July 2021 respectively at S-1. The average concentration of particulate matter ($PM_{10}$) at selected sites namely (S-1) and (S-2) were found to be above the prescribed standard of National Ambient Quality Standards (NAAQS) established by Central Pollution Control Board (CPCB) throughout the monitoring period. The observed highest value for $PM_{10}$ was during January 2020 (198.63 µg/m$^3$ at S-1 and 195.63 µg/m$^3$ at S-2). Whereas observed value of $PM_{10}$ in the month of January 2021 and December 2020 was 198.86 and 196.74 µg/m$^3$ at S-1 and S-2 respectively. Overall ambient air quality index (AQI) was determined. The overall quality of air is observed to be slightly contaminated in the months of December and January (2019, 2020 and 2021) at both stations S-1 and S-2, whereas, in remaining months throughout the monitoring duration, ambient air quality index value was observed to be well within permissible limit.

***Key words:*** *Air Pollution, Pollutants, Sulphur Oxide, Nitrogen Oxide, $PM_{10}$*

## Introduction

Air pollution is the result of multiple human activities and natural calamities. Over the years, a number of natural activities, i.e. volcanoes, forest fires, and lightning releases various air pollutants in to the environment but the concentration of these pollutant in atmosphere has not affected much as is now being done by anthropogenic activities. Hence, anthropogenic activities, such as emissions from the road vehicles, industrial power plants, agricultural activities, wastes disposals from building construction, smelting activities, use of tobacco, and metal-based industries, are considered as main reason for envi-

ronmental degradation and human health (Kampa and Castanas, 2008; Tibuakuu *et al.,* 2018; Rajper *et al.,* 2018). As per WHO report, about 7 million people die every year due to exposure to various air pollutants present in the environment. As per WHO report, 4.2 million premature deaths are caused around the world due to exposure to ambient air pollution (WHO, 2018). In India, ambient air pollution related deaths are ranked at 5$^{th}$ while 7$^{th}$ in case of overall burden on health sector. It has been founded in a study that due to exposure to bad ambient air pollution nearly 6,70,000 people dies annually. According to WHO report, India had most 14 cities in the top 20 world's most polluted cities in terms of particulate matter (WHO 2019). Due to rapid urbanization and industrialisation in India, large number of air pollutants including $CO_2$, $SO_2$, $NO_2$, and dust particles among others are being released in to the environment and hence creating immense pressure on environment and climate. Large number of people are migrating to urban areas for employment and better life as a result number of vehicles has increased and hence increasing the air pollutants in environment (CPCB 2010). Air pollutant are categorised in to two categories including primary pollutant and secondary pollutants. Primary pollutant i.e. $PM_{10}$, $PM_{2.5}$, Gases including; carbon monoxide (CO), nitrogen oxide ($NO_2$), and sulphur dioxide ($SO_2$) etc. are the pollutant that are being released in to the environment directly, whereas, secondary pollutants such as ozone ($O_3$), peroxyacyl nitrates (PAN), nitric acid ($HNO_3$), and sulfuric acid ($H_2SO_4$) etc. are those that are formed in to the environment due to chemical reaction with the primary pollutants (WHO 2018). Presence of air pollutants in to the atmosphere in higher concentration on exposure to animal, plant and human deteriorates the quality of the life (WHO 2018; Burnett *et al.,* 2018; Lu, 2020). US EPA, has established ambient air quality standards for six pollutants namely carbon monoxide, lead, nitrogen dioxide, ground level ozone, particulate matter, and sulphur dioxide and named these pollutants as criteria pollutants. Air pollution is the reason for several acute as well as chronic diseases in human being including asthma, cardiovascular disease, lung cancer, respiratory diseases, wheezing, pulmonary disease etc. (Goldberg, 2008; Williams *et al.,* 2012). Air pollution in Ayodhya is continuously increasing mainly due to rapid urbanisation, therefore the present study is to assess the pattern of air pollutants and status of ambient air quality. In the present work, pollutants particularly $SO_2$, $NO_2$, and $PM_{10}$ are studied and finally status of air quality in Ayodhya.

## Materials and Methods

### Study Area

Ayodhya is one of the holy cities situated at the bank of river Saryu about 130 km east of state capital of Uttar Pradesh, i.e. Lucknow, India. Ayodhya city is situated at 82°122163 E longitude and 26°472563 N latitude and has an elevation of 102 meters above the mean sea level. Ayodhya has humid subtropical climate, summers are long, dry and hot, lasting from late March to July, with temperature ranging from 35 to 45ºC. Whereas, winter temperatures ranges from 6 to 25 °C starting from November to February. Ayodhya receives nearly 1100 mm of annual rainfall out of which more than 85% falls during the month of June to September (southwest monsoon). Ayodhya because of its religious importance has gained enormous attention. Large number of development activities including road and building construction, uncontrolled burning activities, increase in motor vehicle traffic are becoming the main factor for polluting the quality of air. With the aim to assess the quality of ambient air in Ayodhya, study was carried out to monitor the status of quality of air and pollutants from September 2019 to August 2021.

### Sampling sites

Two sites for monitoring the air quality status in Ayodhya city were selected randomly. Namely, Naka Bypass (S-1) with latitude 26.7963° N, longitude 82.2007° E, situated near the Lucknow Ayodhya highway while second monitoring station is established at Hanuman Garhi Chauraha Ayodhya (S-2)with latitude 26.7551° N, and longitude 82.1411° E , situated near the Saryu River. Site S-1 serves as centre for variety of residential activities and vehicular load while S-2 was used to monitor the air pollutants from residential as well as religious activities. Ambient air monitoring at both the sites was carried out during September 2019 to August 2021 and result are presented in this paper. The selected sites has been shown in the figure below.

### Sampling and Procedure

The monitored parameters in this study were $PM_{10}$, $SO_2$, and $NO_2$, by using Respirable Dust Sampler

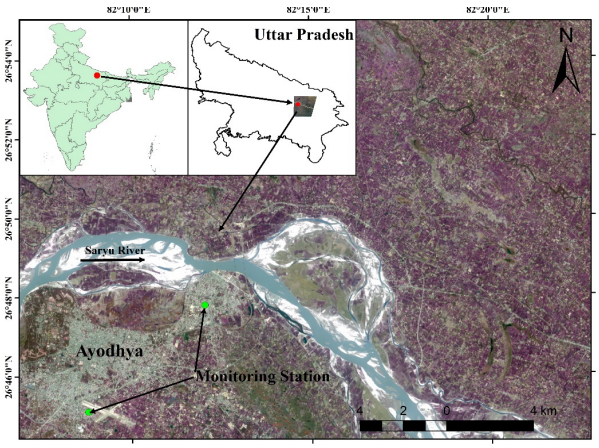


**Fig. 1.** Shows the location of sampling sites of Ayodhya city

(RDS) with a flow rate of 1 $m^3$/min and glass fibre filter paper of 20.3×25.4 cm (8×10 inch) size**.** RDS was placed at 4 meter above the ground level. Sampling was done twice a week 24 hourly at uniform intervals, i.e. at four hours for $SO_2$ and $NO_2$ while at 8 hour for $PM_{10}$. Impinger was placed in RDS for collecting the sample of $SO_2$ and $NO_2$ while glass fibre filter paper was used for collecting the sample of $PM_{10}$. Improved West and Geake method was used for measuring the concentration of $SO_2$ (IS 5182 Part 2 method of measurement of air pollution: Sulphur dioxide), while Modified Jacob & Hochheiser was used for measuring the concentration of $NO_2$ concentration (IS 5182 Part 6 Method for measurement of Air pollution: Oxides of Nitrogen) and Gravimetric method was used for measuring $PM_{10}$ concentration.

### Air quality index

Air Quality Index is a tool, used to describe the Ambient Air quality status of a particular area based on a specific standard. Air Quality Index help in informing public about pollution of an ambient air in a particular area whether on exposure it is harmful or not. Table 1 shows the category of air quality based on the value of air quality. Tiwari and Ali (1987) has suggested the formula for the calculation of Air Quality Index (AQI) as;

$$\mathbf{AQI} = \frac{1}{3}\left[{}^{\mathbf{PM_{10}}}/_{\mathbf{IPM_{10}}} + {}^{\mathbf{NO_2}}/_{\mathbf{INO_2}} + {}^{\mathbf{SO_2}}/_{\mathbf{ISO_2}}\right] \times \mathbf{100} \quad .. \ (1)$$

$PM_{10}$, $NO_2$, $SO_2$ = observed mean value of pollutants $IPM_{10}$, $INO_2$, $ISO_2$ = Standard value of recommended parameter

**Table 1.** Air Quality Rating Scale Based on air quality index (Tiwari and Ali., 1987)

| Numeric category | Air Quality Category | AQI values |
|---|---|---|
| 1 | Very clean | < 10 |
| 2 | Clean air | 10-25 |
| 3 | Fairly clean | 25-50 |
| 4 | Moderately polluted | 50-75 |
| 5 | Polluted | 75-100 |
| 6 | Heavily polluted | 100-125 |
| 7 | Severely polluted | >125 |

## Results and Discussion

Month wise and station wise observations related to air pollutants including; $SO_2$, $NO_2$, and $PM_{10}$ from September 2019 to August 2021 are presented in to the following sections;

### Sulphur Oxide ($SO_2$)

Concentration of $SO_2$, at both stations were found below the prescribed standard established by NAAQs, i.e. less than 80 µg/$m^3$. Figure 2, shows the monthly $SO_2$ concentration throughout the sampling period. At S-1, highest $SO_2$ concentration was observed to be 9.35 µg/$m^3$ in December 2020 whereas 8.35 µg/$m^3$ was the highest $SO_2$ concentration observed at S-2 during December 2020. Whereas, minimum $SO_2$ concentration was found to be 4.33 µg/$m^3$ in May 2020 at S-1 and at S-2, lowest value of $SO_2$ was 3.5 µg/$m^3$ in May 2020. This is due to high wind speed and frequent rainfall during summer and monsoon season. Whereas, higher concentration of

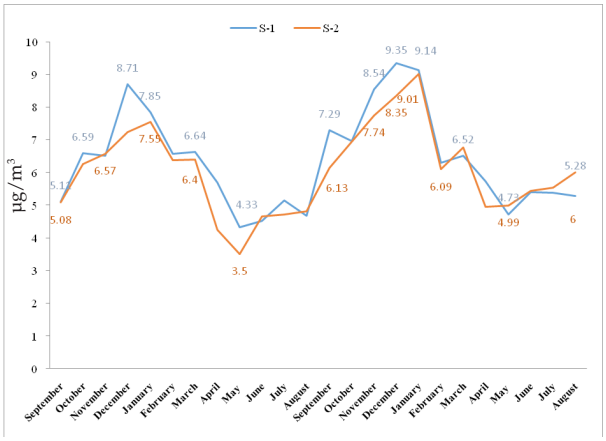


**Fig. 2.** Shows the monthly variation of $SO_2$(µg/$m^3$) from September 2019 to August 2021

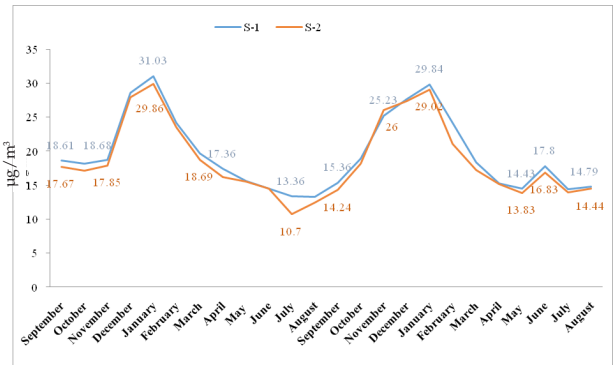


**Fig. 3.** Monthly variation of $PM_{10}$ (µg/m³) in Ayodhya City from September 2019 to August 2021

$SO_2$ was observed in winter mainly due to calm wind speed and less precipitation. Whereas, average $SO_2$ concentration during the whole monitoring period was observed to be lower at S-2, i.e. 6.05 µg/m³ as compared to S-1 i.e. 6.37 µg/m³.

### Nitrogen dioxide ($NO_2$)

The emissions of $NO_2$ at both the stations (S-1 & S-2) was found below the prescribed standard established by NAAQs, i.e. less than 80 µg/m³. Figure 2, shows the monthly $NO_2$ concentration throughout the sampling period. According to the analysis, the average concentration of $NO_2$ during the monitoring duration was found to be higher at S-1 as compared to S-2 as 19.55 µg/m³ and 18.69 µg/m³ respectively. The highest $NO_2$ concentration was observed during January 2020, i.e. 31.03 µg/m³ at S-1 and 29.86 µg/m³ at S-2. Whereas, $NO_2$ concentration decreased after that till monsoon season. Concentration of $NO_2$ was observed higher at S-1 mainly due to higher traffic density.

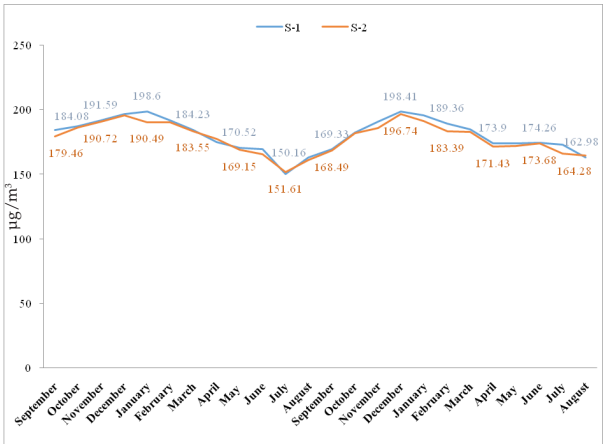


**Fig. 3.** Monthly variation of $NO_2$ (µg/m³) from September 2019 to August 2021

### Particulate Matter ($PM_{10}$)

The concentration of $PM_{10}$ was found to be above the permissible limit established by NAAQs at both the stations through the monitoring period. The concentration of $PM_{10}$ was found to be higher at S-1 i.e. 198.41 µg/m³ in December 2020, whereas 196.74 µg/m³ was found to be highest at S-2 in 2020. The lowest value of $PM_{10}$ was observed to be 150.16 µg/m³ in July 2020 at S-1, while 151.61 µg/m³ was found to be lowest at S-2 in the month of July 2020. Average concentration of $PM_{10}$ during summer season (March-May), was found to be 177.01 & 176.07 µg/m³ at S-1 and S-2 respectively, while during pre-monsoon season (June-August) 165.50 & 165.03 µg/m³ concentration was found at S-1 & S-2 respectively. Whereas, average concentration of 184.17 and 182.13 µg/m³ was record at S-1 & S-2 respectively during post-monsoon season (September-November). Furthermore the average concentration during winter season (Dec-Feb) was observed to be 195.06 & 191.25 µg/m³ at S-1 & S-2 respectively. The average concentration of PM10 was lower during the summer and pre-monsoon and post-monsoon season as compared to winter season is mainly due to higher wind speed and higher rainfall intensity in these seasons as winter season have low wind speed and low rainfall intensity. Figure 4, shows the monthly PM 10 concentration throughout the sampling period.

### Air Quality Status

Equation 1 was used for the calculation of air quality index at both the sites. Based on the quality index value as shown in Table 1, its respective air quality category has been established. From Table 1, it has been found that higher the AQI value, higher is the level of air pollutants and greater the impact on human health. Figure 4 shows monthly variation in

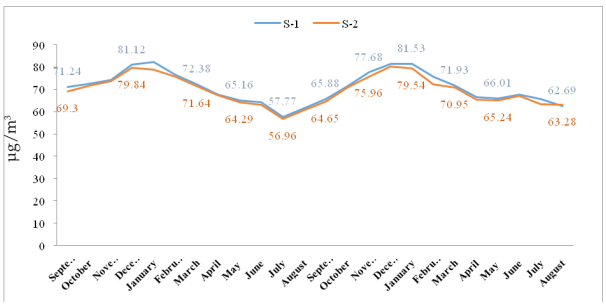


**Fig. 4.** Monthly variation in AQI values in Ayodhya city from September 2019 to August 2021

AQI value in Ayodhya city from September 2019 to August 2021. As per study, the maximum AQI level at S-1 was found in the month of January (2019 & 2020) as (82.4 µg/m³ and 81.53 µg/m³); while at S-2, 79.84 µg/m³ and 80.44 µg/m³ was found to be maximum in the month of December (2019 & 2020). On comparing the AQI value obtained using equation 1 at both the stations (S-1 & S-2), it has been found that AQI level was higher at S-1 than S-2 as 70.94 µg/m³ and 69.74 µg/m³ respectively. This is mainly due to its sampling station location. Air pollution index value, i.e. air pollution to be in the moderate level at both the stations during pre-monsoon, post monsoon and summer season whereas the pollution level was higher in December and January (winter season).

## Conclusion

From the two established stations (S-1 & S-2) an observation on air quality on monthly basis and seasonal basis was made. From the observation it has been found that PM10 is the most predominant contributor in air pollution at both the stations (S-1 & S-2) and the value of air quality index at station S-1 is found to be higher than station S-2. However, at both the stations, the concentration of $SO_2$ and $NO_2$ were found within the acceptable limit. Bad air quality is observed at station S-1 due to its location near the National Highway, as it had large vehicular load on to it whereas station S-2 had slightly less pollutant as compared to station S-1 mainly due to its location near to district road as it remains empty during the night. Furthermore, location of station S-2 is nearer to Holy River Saryu and hence air passing through it carrier's lower pollutant level. According to the conducted study, overall AQI of Ayodhya city is found to be better as compared to other cities of India i.e. Delhi, Kanpur and Lucknow etc.

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