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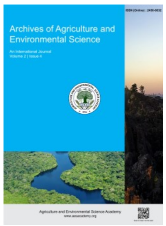

ORIGINAL RESEARCH ARTICLE

CrossMark

Impact of construction activities on the air quality of Agra city, Uttar Pradesh, India

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ABSTRACT

The current research work was carried out to comprehensively assessed the impact of construction activities on the air quality. Seven sites were chosen along the metro line construction in Agra, Uttar Pradesh, India, to meet the study's goals. The monitoring was performed for 24 hours at each site using the respirable dust sampler (RDS) with a gaseous sampling attachment. The raw data was processed to calculate the Air Quality Index (AQI). The data obtained indicate that all the examined sites had PM_{10} (particulate matter having the diameter less than or equal to 10 micron) values above the National Ambient Air Quality Standards (NAAQ) values of 100 µg/m^3, while SS-05 and SS-06 had $PM_{2.5}$ (particulate matter having the diameter less than or equal to 2.5 micron) values above the NAAQ values of 60 µg/m^3. Values of CO, SO_2, and NO_2 were discovered to be lower than the NAAQ standard limits. Because PM10's sub index (Si) was found to be the greatest across all locations, it was determined to be the criterion pollutant among all the metrics. Based on the AQI value, the research area's overall air quality was determined to be moderately polluted. At every location, a variety of management techniques, including mist guns, water spraying, and planting, are regularly used to reduce air pollution. Effective implementation of applied air pollution control measures is required to make the air clean and safe for breathing.

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INTRODUCTION

Air is a vital natural resource that supports life present on the earth. The whole earth is surrounded by the layers of air up to thousands of kilometres (Jain & Mandowara, 2019; Xu *et al.*, 2020). In the hands of the creator, everything is flawless, but when it comes to humans, everything degenerates (Ahmad & Bano, 2015; Yang *et al.*, 2020; Sokhi *et al.*, 2021). In developing countries, urbanization is an inevitable process that leads to rapidly expanding transportation, building, and industrial sectors (Zhang *et al.*, 2022). Most metropolises in India are unplanned, which causes a concentration of people closer to the city centre (Wang *et al.*, 2020). Increased mobility activities due to high population density and poor vehicle maintenance (Li & Yang, 2020) harm human health and air quality (Gulia *et al.*, 2018; Goswami *et al.*, 2024). India's air pollution has surged due to several factors, including rapid population growth (Sah, 2023), a rise in the number of vehicles on the road (Tiwari *et al.*, 2022), the use of fuels with poor environmental performance (Wang *et al.*, 2018), poorly maintained transportation infrastructure, unplanned land use, industrialization (Shikha *et al.*, 2023 Goswami *et al.*, 2024), and, most importantly, ineffective environmental regulations (Ruhela *et al.*, 2022a). The incineration of garbage, the burning of fossil fuels, industrial emissions, wind-blown dirt and road dust, and building activities are some of the ways of continuously introduction of harmful materials into the environment (Lin *et al.*, 2020). Both human and animal health's are negatively impacted by the elevated levels of air pollution (Chen *et al.*, 2018; Bagtasa & Yuan, 2020; Rajak & Chattopadhyay, 2020). Seasonality has always been a role in influencing the concentration of pollution in the lower atmosphere since the effects of gaseous and particle pollutants on human and ecosystem health vary with the season (Orimoogunje & Balogun, 2015; Ruhela *et al.*, 2022b; Goswami *et al.*, 2022 and 2023).

Due to continuously increasing population, the number of vehicles on the roads are also increasing continuously which results in traffic congestion in the cities. To avoid this problem, the construction of Metro lines starts in India. Although metro line construction starts in India in 1972 in Kolkata, but it becomes conventional in the year 2000 with Delhi Metro. At present, India has 902.39 Km operational metro line while 649.56 Km under construction line. Construction of Agra metro line starts in the end of the year 2020. Construction activities generate a lot of dust and gaseous emission due to operation of heavy machineries at the construction sites. Agra is the fourth most populus city of Uttar Pradesh as well as tourist place. Quality of air in Agra is a serious concern as the degraded air quality is responsible for the degradation of Marble of the Taj along with the health of people. The metro line network in Agra is expanding which is also impacting the air quality of the city. Although few studies are available focusing on the source apportionment of air pollution and chemical characterization of the particulate matter but none of the study emphasizes on the effect of construction activities on the air quality of the city. Therefore, the current study was conducted to assess the variation in air quality of the Agra city along the construction of Metro line. The air quality index (AQI) approach was also used to compare the air quality at each site.

MATERIALS AND METHODS

Study area

Agra is situated on the bank of Yamuna River in the Indian state of Uttar Pradesh. With an estimated 1.6 million residents, Agra ranks fourth in the state, twenty third in India. Geographically the Agra city falls in plain category. The climate of the Agra is tropical and sub-tropical. The winter in Agra is warm in comparison to nearby cities. The summer season lasts long followed by light rainy season. Based on a long-term study (2010-2016), the World Health Organization (WHO) placed at 8th place in India in terms of air pollution. All the sampling sites selected for the present study are given in Table 1.

Monitoring and analysis

Monthly ambient air quality monitoring was conducted at the chosen seven locations (Table 1) in the study area. Every month, one full day was dedicated for air quality monitoring at every site within the study area. Using a respirable dust sampler (RDS) with a gaseous sampling attachment, the air quality monitoring program was started in the morning between 7:00 and 11:00 in accordance with the CPCB's conceptual guidelines and common methodology for air quality monitoring, emission inventory, and source apportionment studies for Indian cities. After monitoring, filter papers were stored in plastic zip bags, folded lengthwise, and brought to the lab. After sample, plastic bags with ziplocks containing filter papers were taken to the lab right away to be weighed. The parameters that were examined throughout the research period were PM_{10}, $PM_{2.5}$, NO_2, SO_2, and CO (Table 2).

Air Quality index (AQI)

Air Quality index (AQI) is a mechanism that simplifies complicated data on air quality into a single number so that the public may use and comprehend it. The ratio of the pollutant concentration in ambient air to the standard limit of the pollutant in ambient air is aggregated to compute it. To determine the cumulative effect of pollutants, several researchers computed the AQI for various regions (Ziauddin & Siddiqui, 2006; Xu *et al.*, 2020; Ahamad *et al.*, 2022). The following formula has been used to determine AQI for the five criterion pollutants: PM_{10}, $PM_{2.5}$, SO_2, NO_2, and CO.

$$\text{Air Quality Index (AQI)} = \frac{1}{5} \times \left\{\left(\frac{PM10}{PM10(s)}\right) + \left(\frac{PM2.5}{PM2.5(s)}\right) + \left(\frac{SO2}{SO2(s)}\right) + \left(\frac{NO2}{NO2(s)}\right) + \left(\frac{CO}{CO(s)}\right)\right\} \times 100$$

Where, PM_{10}, $PM_{2.5}$, SO_2, NO_2, and CO are the concentration of respected parameters in the samples air while $PM_{10}(s)$, $PM_{2.5}(s)$, $SO_2(s)$, $NO_2(s)$, and CO(s) are the Standard limit respected parameters in the air.

Table 1. Selected sites for air quality assessment in Agra city, Uttar Pradesh, India.

Sampling site	Code given	Coordinates
Agra College Station	SS-01	Latitude 27.190494, Longitude 78.001031
RBS Station	SS-02	Latitude 27.201381, Longitude 77.994947
Raja Ki Mandi	SS-03	Latitude 21.194684, Longitude 77.997461
Casting Yard	SS-04	Latitude 27.172753, Longitude 78.029129
Mid Shaft	SS-05	Latitude 27.171373, Longitude 78.023284
RBS Ramp	SS-06	Latitude 27.207055, Longitude 77.994167
RBS Batching Plant	SS-07	Latitude 27.205573, Longitude 77.994330

Table 2. Test Methods of parameters, references, their units and Standards.

Parameters	Method of Test	Unit	NAAQS*
Particulate matter (PM_{10})	IS:5182 (Pt-23)-2006 (RA2017)	$\mu g/m^3$	100 (Max.)
Particulate matter ($PM_{2.5}$)	IS:5182 (Pt-23)-2006 (RA2017)	$\mu g/m^3$	60 (Max.)
Nitrogen dioxide (NO_2)	IS:5182 (Pt-6)-2006 (RA 2017)	$\mu g/m^3$	80 (Max.)
Sulphur dioxide (SO_2)	IS:5182 (Pt-2)-2001 (RA 2017)	$\mu g/m^3$	80 (Max.)
Carbon monoxide (CO)	NDIR EPA 600	mg/m^3	4 (Max.)

*NAAQS: National Ambient Air Quality Standards, Schedule-VII, [Rule 3 (3B)], [Part-II-se-3(i)] 16.11.2009.

RESULTS AND DISCUSSION

All the results are presented in Table 3. The precursor gases that generate particulate matter, namely SOx, NOx, NH_3, and non-methane volatile organic compounds, undergo chemical reactions that result in particulate matter ($PM_{2.5}$ and PM_{10}). They consist of a sophisticated blend of inorganic and organic materials. It poses the biggest risk since it can cause health issues and early death when it enters delicate areas of the respiratory system (Chen *et al.*, 2018; Franceschi *et al.*, 2018; Licbinsky *et al.*, 2020). The lowest value of PM_{10} (108.23±9.78 µg/m^3) was recorded at SS-01, while SS-05 recorded the highest value (114.05±14.09 µg/m^3), and the average value was determined to be 111.03±1.96 µg/m^3 across all sites. Besides the application of a lot of control measures, the value of PM_{10} is still beyond the NAAQ threshold (100 µg/m^3) suggesting that there should be more emphasize on the dust control activities. Tiwari *et al.* (2020) observed the values of PM_{10} (137.09 µg/m^3) in urban areas. Mostly the coarser particle of dust (PM_{10}) was found within the 100 meter of stretch around the construction site which results in higher AQI (Singh *et al.*, 2017; Phogat *et al.*, 2022). The major source of PM_{10} may be the soil and roadside dust, and burning of Coal, biomass, fly ash as discussed by Nagar *et al.* (2021) while performing the source apportionment analysis of air around Taj Mahjal in Agra city.

An essential metric in systems for assessing air quality is $PM_{2.5}$ concentration. The relevance of analyzing and forecasting $PM_{2.5}$ concentrations has increased due to increased public awareness (Licbinsky *et al.*, 2020; Ruhela *et al.*, 2022c). Since of their tiny size, these particles are quite dangerous since they can penetrate the respiratory system and impair lung function. The lowest value of $PM_{2.5}$ (54.60±1.78 µg/m^3) was recorded at SS-07, the highest (62.22±7.52 µg/m^3) at SS-06, and the average value was determined to be 58.48±2.87 µg/m^3. Every measurement was determined to be lower than the NAAQ threshold (60 µg/m^3). Kulshreshtha *et al.* (2021) observed the two to seven times increase in the values of particulate matter during Diwali days. Nagar *et al.* (2021) observed the comparable outcome (65 µg/m^3) in their study. Sah (2023) declared that carcinogenic risk of smaller particulate matter ($PM_{2.5}$) is higher in children in comparison to adults. The major source of $PM_{2.5}$ may be the burning of Coal, biomass, fly ash, and vehicular movement (Tiwari *et al.*, 2020; Nagar *et al.*, 2021).

The collective term for all oxides of nitrogen, including nitric oxide (NO) and nitrogen dioxide (NO_2), is nitrogen oxide (NOX= NO+NO_2). These can be produced by natural or anthropogenic processes, such as lightning and soil microbiological processes, as well as by the burning of fossil fuels, thermal power plants, and transportation activities (Seinfeld & Pandis, 2016; Bagtasa & Yuan, 2020). Numerous investigations of NO_2 emissions have revealed that they have a major impact on Earth's tropospheric chemical processes (Choo *et al.*, 2020; Bhutiani *et al.*, 2021). Of all the locations, SS-07 had the lowest NO_2 value (13.05±0.48 µg/m^3), SS-05 had the highest value (13.76±0.56 µg/m^3), and the average value was 13.28±0.31 µg/m^3. Ozden *et al.* (2005) and Saxena & Shekhawat (2017) found a result that was roughly identical. Every measurement was determined to be lower than the NAAQ threshold (80 µg/m^3). Nagar *et al.* (2021) also observed the values of NO_2 emissions (13.00±5.0 µg/m^3) like the current study. Among all the sites, minimum value (27.00±1.42 µg/m^3) of SO_2 was observed at SS-04 while the maximum (29.66±1.09 µg/m^3) was observed at SS-02 and the average values was found 28.36±0.84 µg/m^3. All the values were found below the NAAQ value which is 80µg/m^3. Ghosh & Parida (2015) obtained the more or less similar results of gaseous pollutant in the air quality of concerned areas. The incomplete combustion of fuel, either from industry or automobiles, produces carbon monoxide (CO) gas. This gas also originates from forest fires (Gulia *et al.*, 2018). The lowest CO value (1.15±0.03 µg/m^3) was recorded at SS-01, the highest (1.20±0.02 µg/m^3) at SS-05, and the average value was 1.17±0.02 µg/m^3 across all sites. El-Sharkawy (2013) noted a finding that was roughly identical. The study's observations verified that the transportation sector is the primary source of carbon dioxide emissions. Lin *et al.* (2020) revealed the emission of different gases such CO_2, NO_X, and SO_2 during the railway line construction in China due to combustion of fossil fuels in the machinery.

Table 3. Average values of physicochemical parameters of air at different studied sites.

Site /Parameters	PM10 (µg/m^3)	PM2.5 (µg/m^3)	NO_2 (µg/m^3)	SO_2 (µg/m^3)	CO (µg/m^3)
SS-01	108.23±9.78	56.45±1.94	13.25±0.61	28.05±1.11	1.15±0.03
SS-02	109.29±10.81	57.08±2.57	13.53±0.61	29.66±1.09	1.19±0.03
SS-03	111.40±10.49	57.34±1.05	12.83±0.78	28.61±1.20	1.15±0.04
SS-04	110.37±11.22	59.82±4.10	13.26±0.65	27.00±1.42	1.15±0.04
SS-05	114.05±14.09	61.85±7.30	13.76±0.56	28.30±0.99	1.20±0.02
SS-06	111.28±14.15	62.22±7.52	13.26±0.20	28.99±0.78	1.17±0.02
SS-07	112.55±12.92	54.60±1.78	13.05±0.48	27.94±1.42	1.17±0.03
Average± SD	111.03±1.96	58.48±2.87	13.28±0.31	28.36±0.84	1.17±0.02

Table 4. AQI values of different sites and their air quality.

Sites	AQI	Quality
SS-01	56.53	Moderate air pollution
SS-02	57.62	Moderate air pollution
SS-03	57.51	Moderate air pollution
SS-04	57.81	Moderate air pollution
SS-05	59.95	Moderate air pollution
SS-06	59.42	Moderate air pollution
SS-07	56.81	Moderate air pollution

Table 5. Air Quality Index (API) and its interpretation.

Index Level	Interpretation of Index value For Air (Rao and Rao, 1986)
0-25	Clean air
26-50	Light air pollution
51-75	Moderate air pollution
76-100	Heavy air pollution
>100	Severe air pollution

Assessment of air quality using Air Quality Index (AQI)

The parameter that was shown to have the greatest Si value was designated as the criterion pollutant for that site. The higher the AQI number, the worse the effects will be on the health of plants and animals as well as property damage. AQI was categorized into five groups based on how it affected human health. In Table 4, the categories were listed. Table 5 displayed the findings of AQI. The AQI was computed both parameter- and site-wise. Among all the examined metrics at all the analyzed sites, PM_{10} is regarded as a criterion pollutant. Because CO has the lowest Si value of all the factors examined, it is regarded as the least important parameter. There were 56.53, 57.62, 57.51, 57.81, 59.95, 59.42, and 56.81 AQI values at SS-01, SS-02, SS-03, SS-04, SS-05, SS-06, and SS-07, respectively. Based on a comparison of the acquired AQI findings with the standard scale provided by Rao & Rao (1986), all the sites under investigation had moderate air pollution because of construction-related activities. The Municipal Corporation is concerned as none of the sites fell within the clean air class category.

Conclusion

The current study on air quality evaluation was conducted at a few chosen locations in Agra city along the Metro line construction. The information was transformed into a form that the general public could comprehend by calculating the AQI, which allowed the places under study to be ranked according to pollution levels. Due to on-going building operations in the city, the acquired data show that there is a higher concentration of bigger dust particles in the region, which is why PM_{10} levels were found to be over the standard limit at all the monitoring sites. At just two locations (SS-05 and SS-06), smaller dust particle levels were discovered to be over the typical limit. Values for gaseous contaminants were discovered to be lower than the NAAQ regulatory limits. According to the acquired AQI values, all the locations have moderate air pollution, with PM_{10} being the primary contributing component. As a result, PM_{10} may be regarded as a criterion pollutant for the city of Agra. Construction businesses used various control methods, such as mist guns, water spraying, and plantations, at all of their sites to mitigate air pollution. However, effective execution is necessary to really manage air pollution.

DECLARATIONS

Author contribution statement

Conceptualization: M.R. and F.A.; Methodology: P.V.; Software and validation: P.V. and F.A.; Formal analysis and investigation: P.V.; Resources: P.V.; Data curation: P.V.; Writing—original draft preparation: F.A.; Writing—review and editing: P.V. and M.R.; Visualization: S.B.; Supervision: M.R. and F.A.; Project administration: M.R.; Funding acquisition: None. All authors have read and agreed to the published version of the manuscript.

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