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Analyzing the Environmental Impact on Tourism in Agra : Air Pollution Case Study

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Abstract: The tourism industry is a rapidly growing industry in India, and the utmost importance is given to the tourism and hospitality sectors of India for their excellent contribution to the country's economic development. Unfortunately, most of the prime tourism destinations in India suffer from pollution-related issues, especially, air pollution, which damages the destination's image among visitors. The adverse effect of air pollution impacts tourists' minds, and they often avoid some popular destinations and consider relatively less popular spots to visit. Agra holds a prominent place on India's tourist map for the world-famous Taj Mahal. Millions of visitors come to the city, attracted by the beauty of its white marble monument. However, Agra suffers from severe air pollution issues, and it damages the beauty of the Taj Mahal. The researchers depicted a clear scenario of the air quality of Agra city and carried out a detailed study of air pollution, before, during, and after a post-pandemic period with the help of satellite data, AQI data by CPCB, and QGIS software to find out the major reasons for the pollution so that resilience can be obtained and precautionary measures can be taken by the competent authorities.

Keywords: Air Quality Index, PM_{10}, $PM_{2.5}$, SPM, SO_2, NO_2 pollutants,

Introduction

India offers diversified tourism products to the world. The country, with its excellent natural, man-made, and symbiotic tourism resources, attracts global visitors. India is also culturally very rich due to its historic past. Different invaders from various dynasties conquered and ruled India. They have also created forts, palaces, and monuments of different ages, which have made the country extraordinarily rich in cultural resources. The major tourist spots that attract both domestic and international visitors hold many historical monuments. The Taj Mahal, the romantic white-marble monument of India, is located in UP, India. Millions of visitors come to India to experience the beauty and pride of the Taj Mahal. Taj Mohatsav, a famous ten-day-long carnival, takes place in Agra in February. Taj Mohatsav provides a vibrant platform for tourists to experience India's extravagant culture, cuisine, art and crafts, music, and dance in one place. A huge concentration of the domestic and international population visits Agra to experience the most beautiful historical place in India. Tourism has always had both positive and negative impacts. So pollution is one of the prime negative impacts of Agra. Agra ranks within the top five polluted cities of India and mostly suffers from poor air quality. The researchers have carried out a comparative study of air pollution in Agra with the help of satellite data and modern technological tools like QGIS software. India had a long lockdown period, and vehicle and other movement was restricted. So AQI data from 2019 to 2021 was used for comparison purposes. The researchers have also offered scientific solutions to the problem of setting up a better pollution-free environment for the beautiful city so that it can become a tourist's paradise and can enhance environmental sustainability.

The CPCB of India describes air quality that considers the volume of various pollutants in the atmosphere along with their acceptable or permissible levels, which are commonly mentioned as standards (National Air Quality Index, CPCB, India, 2015). It indicates the quantity of minute suspended particles and other chemical compounds like oxides of carbon, sulfur-dioxide, nitrogen-dioxide, and ozone that exist in the atmosphere. Air quality surpasses all extents within the atmosphere, ranging from local to global, providing feedback at each arena. It is responsible for several adverse impacts on health, the environment, climate and monuments (Monks et al., 2009). "The Air Quality Index" is a tool to measure and publish information on air quality like "good, satisfactory, and poor" and its associated health impacts. (National Air Quality Index, CPCB, India, 2015).

The intensity of air pollution is generally expressed as Air Quality (Monks et al., 2009). Jacobson defined pollution as a sufficiently high concentration of gases or emitted anthropogenically aerosol particles which cause direct or indirect damage to climate, ecosystems, and heritage (Jacobson, 2002). Various air pollutants, such as carbon monoxide (CO), nitrogen oxides (NOx), sulfur dioxide (SO_2), various forms of particulate matter (SPM, $PM_{2.5}$ and PM_{10}), Volatile Organic Compounds (VOCs), surface ozone (O_3), and heavy metals (cadmium, mercury), are responsible for adversely altering the atmospheric composition (Kampa and Castana, 2007). According to World Health Organization, in 2016, it is reported that 4,200,000 premature deaths worldwide per year were caused by ambient (outdoor) air pollution in both urban and rural areas. Also, about 58 percent of the deaths caused by ambient air pollution resulted in strokes and atherosclerotic heart disease, while the other hand, 18 percent of fatalities were caused by severe conditions resulting from pulmonary obstruction like chronic bronchitis and emphysema and acute infections in lower respiratory organs, and 6percent of fatalities were caused by lung cancer (World Health Organization, 2016).

Initially, the notion was, only industrialized and developed countries were prone to the ravages of air pollution. However, it has been noticed that even middle-income and less-developed countries encounter adverse consequences from air pollution. However, worldwide, several regions experienced alteration in the quality of air during lockdown measures adopted during the pandemic situation; such changes might spatially vary over different regions due to variation in the discharged levels of pollutants which consists of vehicular emissions, combustion of fossil fuels and industrial productions (Kerimray, et al., 2020). On the global level, a few countries can be cited where a significant variation in the air in terms of quality could be monitored because of precautionary measures to curb the pandemic situation, such as lockdowns due to reductions in emissions from industries, vehicles, and power generation. For example, in Almaty of Kazakstan, during the lockdown, the $PM_{2.5}$ concentration lowered by 21 percent (varying between 6–34percent) in 2020 than the average $PM_{2.5}$ calculated on similar days in 2018–2019. However, the $PM_{2.5}$ concentration still exceeded the WHO standard. Also, the CO and NO_2 concentrations were substantially reduced, respectively, by 49 percent and 35 percent (Kerimary et al., 2020).

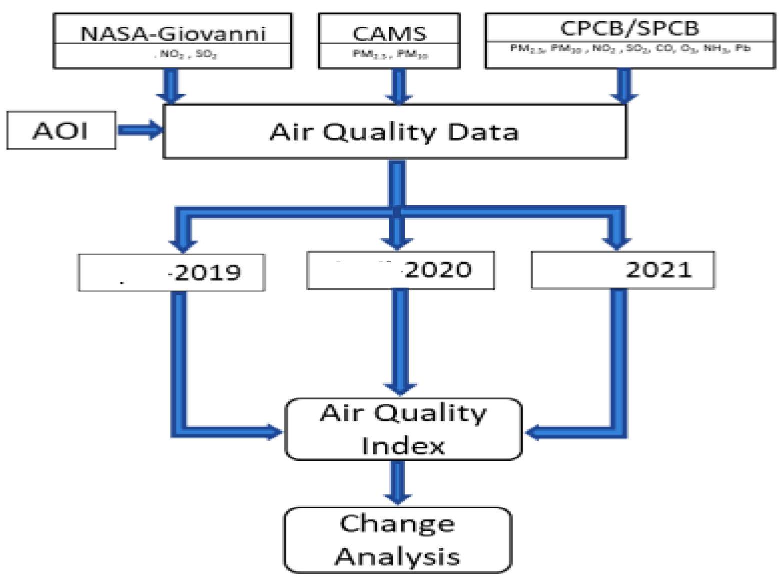
Besides, Nitrogen Dioxide concentration showed extensive reductions of approximately 53 percent in urban areas of Europe and 57percent in Wuhan, China, when compared to the previous 3 years average level (2017–19). $PM_{2.5}$ concentrations also decreased by 8 percent and 42percent in urban regions of Europe and Wuhan, respectively (Ching and Kajino, 2020). Also, results show that human activities in the Yangtze Delta Region in China lowered noticeably due to the pandemic; industrial and vehicular emissions were significantly reduced, which resulted in the lowering of SO_2, NOx, $PM_{2.5}$ and VOCs discharge by almost 15–27 percent, 29–47 percent, 27–46 percent and 37–57 percent during January to 31st March 2020, approximately (Li et al., 2020). The daily mean of $PM_{2.5}$ and NO_2 concentrations within the New York City region between the January and May in 2020 was reduced by 36 percent and 51percent, respectively (Zangari et al., 2020). Although worldwide studies demonstrate improvement in the quality of air owing to reasons like social distancing and lockdown measures due to pandemic, notable variation in New York city were not observed over the years 2015–2019, which might have occurred due to the analysis of both short- and long-term air quality variation (Zangari et al., 2020).

Like several countries, the influence of constricted human activities during the pandemic also had a positive consequence on the air quality of India. All over India, in comparison to previous years, $PM_{2.5}$, PM_{10}, CO, and NO_2 decreased by around 43 percent, 31 percent, 10 percent, and 18 percent, respectively, possibly due to lockdown measures. However, there was a proportional increase in the level of O_3 by 17 percent (Sharma et al.,2020).In contrast to other mentioned pollutants, sulfur dioxide (SO_2) levels showed an increasing trend in the megacities of Mumbai, Bengaluru, and Kolkata (Sathe et al., 2021). The AQI in north, south, west, east, and central India showed a decreasing trend of approximately 44 percent, 33 percent, 32 percent, 29 percent and 15 percent, respectively (Sharma et al., 2020). The AQI lowered by 30 percent in 2020 compared to the preceding years; among the most polluted cities of India, Delhi observed the maximum positive impact in AQI with a reduction of almost 49percent. During the pandemic, the eminent pollutant changed to O_3 in Gaya, Kolkata, Kanpur and Nagpur, while, in Patna and Agra, NO_2 emerged as the imperious pollutant (Sharma et al., 2020).

The quality of air in different cities of India, pre-lockdown, however, portrays a different tale. In the database published by the WHO in 2018, which covered hundred countries worldwide between 2011 and 2016, 14 cities out of the listed top 15 cities reported dangerous levels of $PM_{2.5}$ pollution from India. According to a WHO report released in 2018 among various megacities worldwide, Delhi occupies the apex position in the list for PM_{10} Pollution (Guttikunda, Nisadh and Jawahar, 2019). Delhi, Agra, and a few other cities like Mumbai, Kolkata, Chennai, and Hyderabad were repeatedly covered in various research studies conducted over years since 2000 to identify the potential sources of $PM_{2.5}$ and PM_{10} (Guttikunda, Nisadh, and Jawahar, 2019). The volume of PM (particulate matter) is higher in Agra than in other urban regions in India (Gupta, 2016). The SO_2 level of both the cities, Delhi and Agra, was at par with the annual standard of CPCB, which accounts for50 µg/m3, while in the case of NO_2, the level exceeded the annual standard of 40 µg/m3 in both the cities (Guttikunda, Nisadh and Jawahar,2019).

Methodology

To obtain an accurate result, the research is carried out by collecting various open-source data sources, such as NASA, CPCB, and others, and carefully analyzing them using QGIS software. Concentrations of NO_2 (0.25° level-3 (L3) daily OM Itropospheric) for April 2019, 2020 and 2021 were acquired from the Giovanni interface (https://giovanni.gsfc.nasa.gov/giovanni/), and $PM_{2.5}$ and PM_{10} were derived from the NASA (GES DISCNASA). Other station data were obtained from CPC archived data. PM_{10}, $PM_{2.5}$, SPM, SO_2, and NO_2 levels in the air were critically measured in the research.



Flow Chart 01: Showing the methodology of the current study.

Study Area (Agra)

Agra district is located in Uttar Pradesh, lying between latitudes 26°44' and 27°24' North and longitudes 77°28' and 78°54' East (District Census Handbook, 2011). It forms a part of the southern upper Ganga plain (District Census Handbook, 2011). The most distinct feature of the district's topography is the Yamuna river's presence, along with its tributaries, the Chambal and the Utangan (District Census Handbook, 2011). The climate of Agra is semi-arid, lying in a subtropical humid climatic zone (Saxena and Raj, 2021). As per 2011 Census data, the total population of Agra is 4.4 million, and about 23 thousand tourists visit Agra per day (District Census Handbook, 2011; Gupta, 2016). The population density of Agra is 1,094 persons per sq. km (District Census Handbook, 2011).

Agra is endowed with a profound history and is enriched with numerous historical monuments (District Census Handbook, 2011). The number of licensed vehicles in Agra accounts for 580,396, of these, 27,462 are used for transportation (Saxena and Raj, 2021). Thriving small-scale industries consisting of handicrafts, leather products, iron factories, the tourism industry, and agriculture form the foundation of Agra's economy (Guttikunda, Nisadh, Jawahar 2019). The main industrial composition of Agra consists of two thermal power plants, iron and leather industries, two coal-based railway industries, electronic equipment manufacturing, and a brick industry (Saxena and Raj, 2021). Other than the manufacturing units situated within Agra, the manufacturing units like the glass factory in Firozabad and the Mathura Refinery, which are also situated close to Agra, also contribute to the severe air pollution in Agra (Saxena and Raj, 2021). The city, situated on the banks of the river Yamuna, is eminently known for the Taj Mahal, which UNESCO has proclaimed a World Heritage site. It attracts an average of 8 million tourists per year (Guttikunda, Nisadh, Jawahar 2019). The intricate work of the Taj Mahal carved out of white marble, is severely affected due to the rise in pollution levels (Guttikunda, Nisadh, Jawahar 2019). To protect the heritage, the Supreme Court in 2000 proclaimed a safety zone of 50 km surrounding the Taj Mahal termed the "Taj Trapezium Zone" (TTZ), which ought to be an industrial and vehicular pollution-free zone (Guttikunda, Nisadh, Jawahar 2019). However, this measure went in vain as the impact was inconsequential, leading to the exponential rise in $PM_{2.5}$ levels in Agra, which ultimately resulted in the ranking of the city in 2016 as the 4th-most polluted city in India (Guttikunda et al., 2019; Kumar et al., 2020).

Data Analysis and Discussion

Parameters:

PM_{10} (Particulate Matter) The PM_{10} consists of those particulate matter whose aerodynamic diameter is less than 10. They have the highest lung penetration affinity, which results in increased respiratory and cardiovascular diseases and, in extreme cases, even premature demise (Guttikunda, 2012). In ambient or outdoor air, the highest limit of 24 h average of PM10 as recommended by WHO in 2006 is 50 mg/m3 and CPCB in 2009 set the permissible limit at 100 mg/m3 (Garg, Kumar and Gupta, 2021). Since 2005, the volume of PM_{10} has consistently increased and ultimately accounted for a rise greater than 2.5 times (Guttikunda, 2012). In 2010, the yearly mean outdoor PM_{10} concentrations accounted for 260 µg/m^3, which is almost four times higher than the national standard and 13 times greater than the guidelines mentioned by the World Health Organization (Guttikunda, 2012). Prominent sources of PM_{10} consist of the combustion of coal, kerosene, fossil fuels, biomass, and dust (Guttikunda et al., 2019)

$PM_{2.5}$ (fine particulate matter)—According to the USEPA, $PM_{2.5}$ includes fine particles that are inhaled with diameters of 2.5 micrometres and smaller. $PM_{2.5}$ as a pollutant came into consideration in 2009 and was first measured in 2016 at manual stations (Guttikunda, Nisadh, Jawahar 2019). The highest standard set for $PM_{2.5}$ in ambient air for a 24 h mean is 25 mg/m3 and 60 mg/m3, as mentioned by WHO (2006) and CPCB (2009), respectively (Garg, Kumar, and Gupta, 2021). $PM_{2.5}$ has more influence, even when it has a low concentration in the atmosphere, and it is often linked to several hazardous impacts on health when compared to other pollutants (Saxena and Raj, 2021). Industrial and vehicular exhausts, domestic cooking and heating, open burning of waste, diesel generator sets, and road and construction dust are the prominent sources of ambient $PM_{2.5}$ Pollution (Guttikunda et al., 2019)

SO_2 (Sulphur Dioxide): SO_2 as a gas is colourless and with a sharp odour (WHO, 2018). The main origin of SO_2 is fossil fuel (coal and oil) incineration and the smelting of sulfide-rich mineral ores. The anthropogenic sources consist of fossil fuel combustion for domestic purposes, and power generation for power and transport (WHO, 2018). The standard set for SO_2 for mean 24 h byCPCB(2009) is 80 mg/m3 whereas the standard set by WHO is 40 mg/m3 in ambient air(2006) (Garg et al.,2021).SO_2 mainly causes respiratory diseases, affects the lungs, and is responsible for irritation in the eyes (WHO, 2018). In combination with water, SO_2 forms sulfuric acid; which forms the main constituent of acid rain which is a major cause of deforestation (WHO,2018).

NO_2 (Nitrogen Dioxide)–NO2 is an oxidant gas that is primarily produced due to fossil fuel combustion. It is responsible for triggering asthma (Shima and Adachi, 2000). Nitrate aerosols are products of NO_2, and they constitute an important fraction of $PM_{2.5}$, in the existence of ultraviolet light, it becomes a major component of ozone (WHO, 2018).The standard of NO_2 for an average of 24 h average accounts for 20 mg/m3 and 80 mg/m3 as set by WHO and CPCB respectively in ambient air (WHO, 2006; CPCB, 2009),(Garg et al., 2021). Major sources of NO_2 include fossil fuel incineration (i.e., vehicular emissions) and large industries. (Guttikunda, Nisadh, Jawahar 2019).

SPM (Suspended Particulate Matter) – SPM is usually defined as particles varying from lesser than 10 µm in diameter to particulates lesser than 2 µm in diameter (Kuwata and Nishikawa, 2005). The standard set by the (CPCB, 2009) for SPM is 140 µg/m3 and the annual mean standard mentioned by WHO (2006) is 20 µg/m3 (Kumar, 2009). The SPM mainly originates from incinerators, boilers, and automobiles. They severely affect the human lungs and respiratory system, leading to respiratory diseases. SPM is also produced by chemical reactions in the presence of light with different gaseous substances existent in the atmosphere (Kuwata and Nishikawa, 2005).

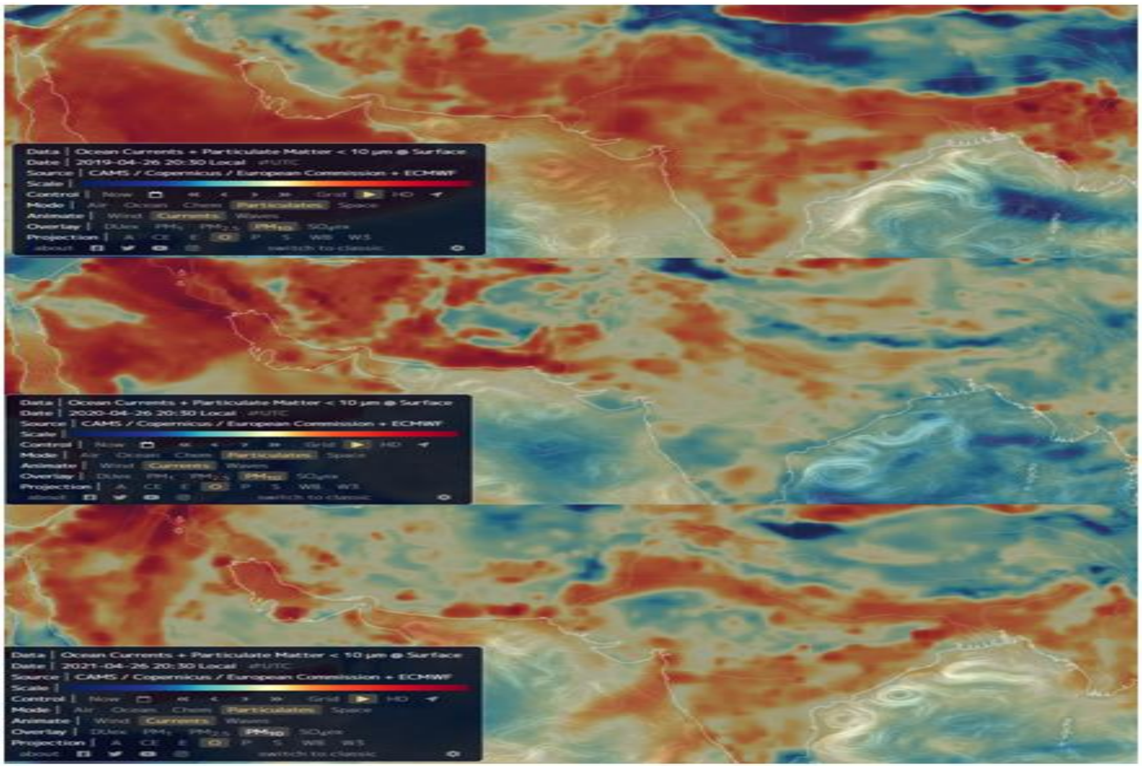


Figure 01: Agra - Variation in concentration from April 2019 to 2021 of PM10 (ug/m^3). Complete lockdown in April 2020 and again rose to a moderate level in April 2021.Source: Created by Author, 2021.

The quality of air in Agra also had has temporary improvement due to the COVID-19 lockdown. The average AQI of Agra pre to post-lockdown improved from moderately polluted (AQI: 101–250) to a satisfactory air quality zone (AQI: 51 to 100) (Gautam et al., 2020). The mean volume of $PM_{2.5}$ in Agra before the pandemic was 56.1 µg/m3, which noticeably decreased to 24 percent during the lockdown, while the NO_2 level reduced by 9.9 percent. In addition, the average concentration of Carbon monoxide reduced from 1.1 mg/m3 to 1 mg/m3 within duration of pre to post-lockdown, which accounts for 9 percent.

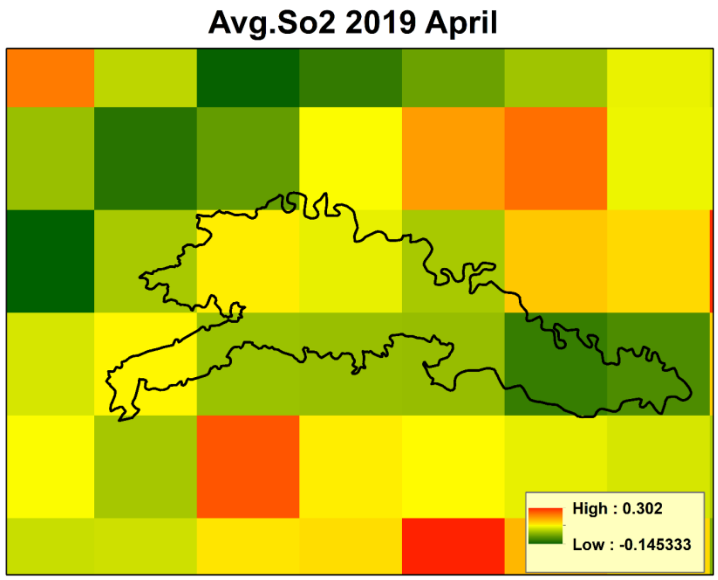


Figure 02: Average SO2 Concentration in Agra in April'2019. Source Created by Authors, 2021.

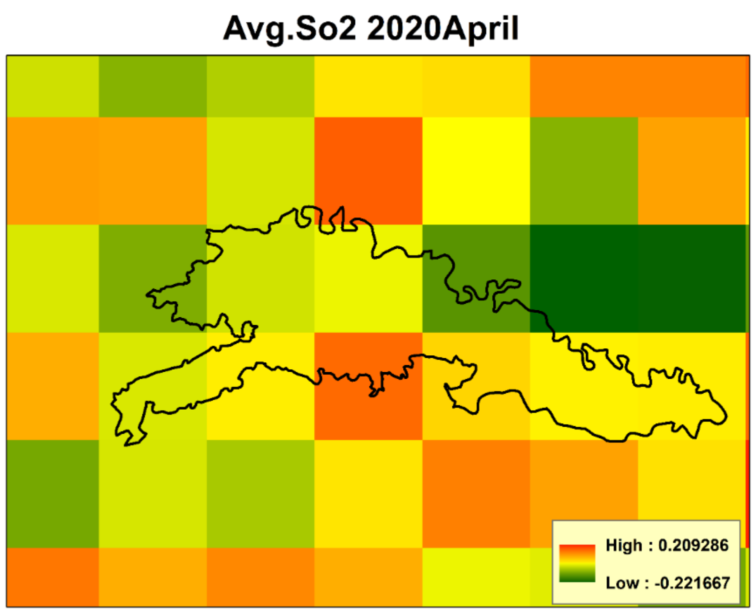


Figure 03: Average SO2 Concentration in Agra in April'2020. Source Created by Authors, 2021.

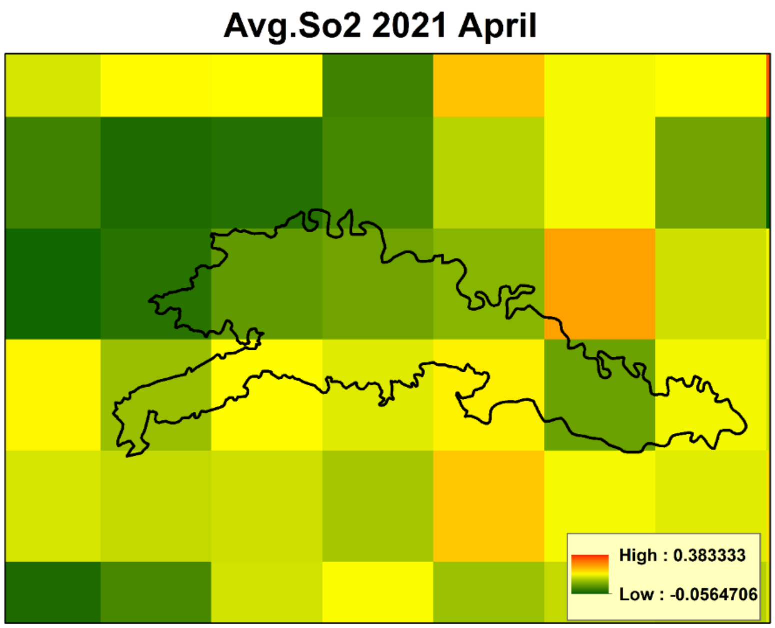


Figure 04: Average SO_2 Concentration in Agra in April'2021. Source Created by Authors, 2021.

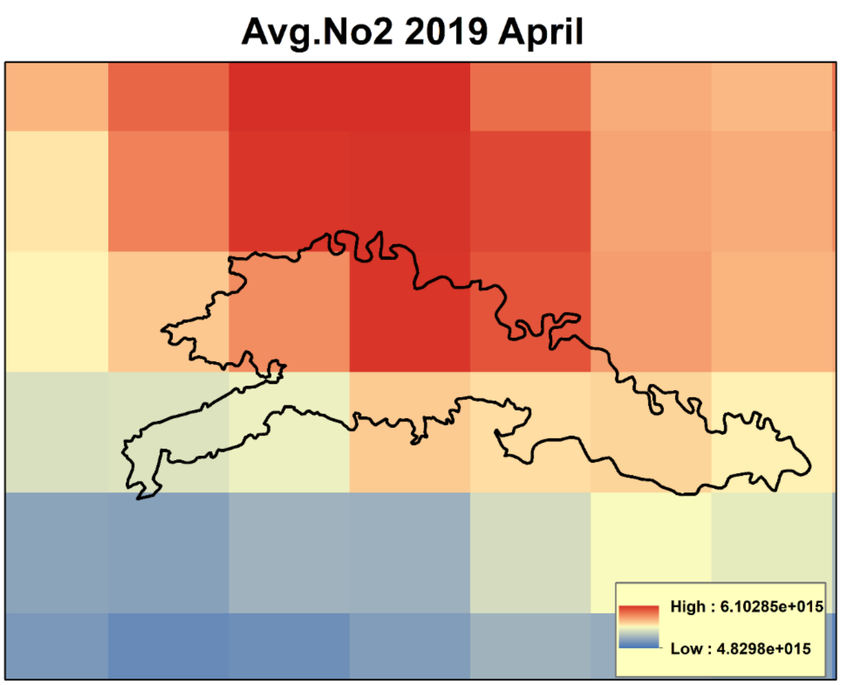


Figure 05: Average NO_2 Concentration in Agra in April'2019. Source Created by Authors, 2021.

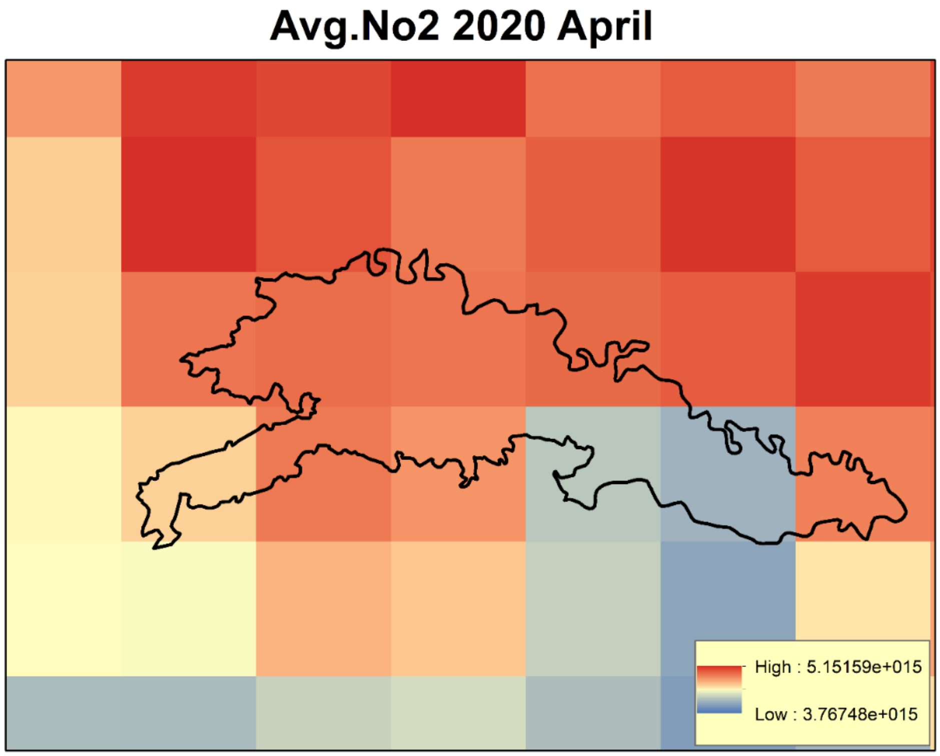


Figure 06: Average NO_2 Concentration in Agra in April'2020. Source Created by Authors, 2021.

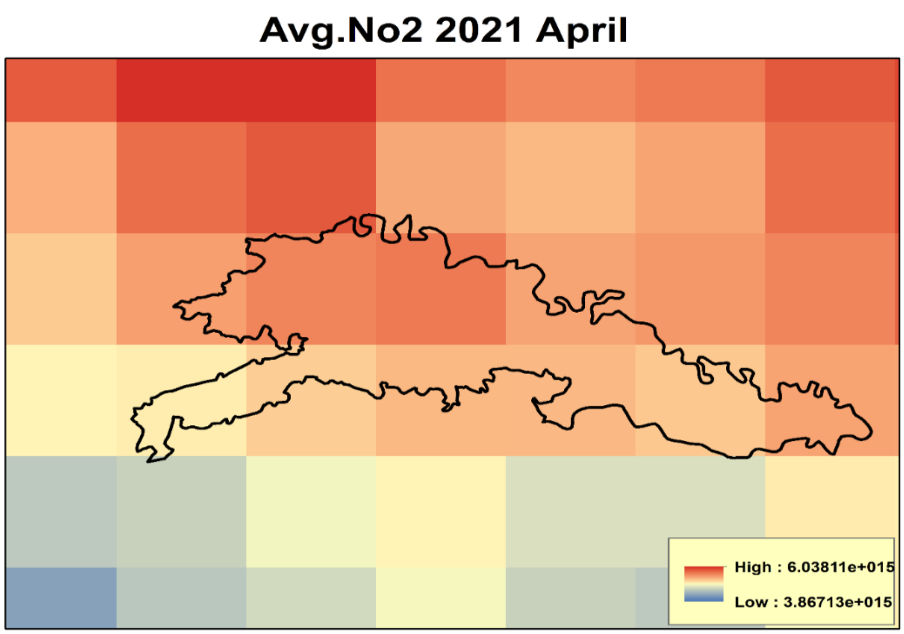


Figure 06: Average NO_2 Concentration in Agra in April'2021. Source Created by Authors, 2021

		TAJ MAHAL				
Year	Date	Sulphur Dioxide (SO2)	Nitrogen Dioxide (NO2)	Fine Particulate Matter (PM2.5)	Particulate Matter (PM10)	Suspended Particulate Matter (SPM)
April,2021	1.4.2021	4	31	37	465	x
	3.4.2021	4	17	55	158	273
	4.4.2021	4	58	100	282	424
	5.4.2021	7	27	70	207	446
	6.4.2021	4	12	60	219	600
	7.4.2021	4	27	67	266	677
	8.4.2021	5	33	52	250	403
	10.4.2021	4	45	68	200	357
	11.4.2021	4	57	72	223	332
	12.4.2021	4	60	77	185	376
	13.4.2021	4	53	65	196	420
	17.4.2021	4	23	33	Low Representative	Low Representative
	19.4.2021	4	40	61	159	343
	20.4.2021	4	22	33	146	399
	22.4.2021	4	31	35	65	174
June, 2020	6.6.2020	x	x	38	x	x
	7.6.2020	x	x	28	x	x
	8.6.2020	4	9	43	83	124
	9.6.2020	4	9	49	82	209
	10.6.2020	4	9	45	132	265
	11.6.2020	4	9	x	127	366
	13.6.2020	4	9	39	94	185
	14.6.2020	4	9	23	86	152
	15.6.2020	7	9	26	59	164
	16.6.2020	4	9	28	40	125
	17.6.2020	4	9	25	84	158
	18.6.2020	4	9	26	61	204
	19.6.2020	4	9	32	122	342
	22.6.2020	4	9	26	83	301
	23.6.2020	4	9	39	78	140
	24.6.2020	4	9	x	35	90
	25.6.2020	4	9	19	103	157
	26.6.2020	4	9	25	60	260
	29.6.2020	4	9	25	77	297
	30.6.2020	12	9	34	77	245
April,2019	1.4.2019	7	36	53	163	234
	2.4.2019	4	22	77	133	276
	3.4.2019	7	22	71	155	270
	4.4.2019	4	15	95	193	349
	6.4.2019	4	22	72	133	367
	7.4.2019	4	9	51	117	372
	8.4.2019	4	9	48	88	308
	9.4.2019	4	9	67	128	293
	10.4.2019	4	29	83	141	355
	11.4.2019	7	11	75	214	333
	13.4.2019	4	13	50	182	372
	14.4.2019	4	9	66	204	359
	15.4.2019	4	11	83	296	557
	16.4.2019	4	31	35	111	305
	20.4.2019	4	46	27	123	193
	21.4.2019	4	23	23	176	299
	22.4.2019	4	24	71	155	374
	23.4.2019	8	11	34	165	421
	24.4.2019	4	9	46	181	466
	25.4.2019	4	15	57	189	454
	27.4.2019	4	13	82	164	513
	28.4.2019	4	9	82	248	428
	29.4.2019	4	20	100	189	431
	30.4.2019	4	17	80	191	379

Figure 07: Comparative Analysis of SO_2, NO_2, $PM_{2.5}$, PM_{10} and SPM of Taj Mahal Area (Agra). Source CPCB Data, 2021

Figure -7 clearly indicates that the air quality of Agra Taj Mahal area is very pure during lockdown period (June’ 2020). It fulfills all compliance of World Health organization related to AQI. The major reasons for the purity are lockdown due to pandemic situation. All human activities were stopped in the above-mentioned time-frame.

Conclusion

The current research clearly exhibits that the COVID-19 global pandemic lockdown directly impacts enhanced atmospheric air quality in Agra, as demonstrated by significant reductions in most air contaminants, specially $PM_{2.5}$, PM_{10}, SO_2, and NO_2. The decreased concentrations of air pollutants are under the permitted ceilings defined by the CPCP guidelines. These decreases in Earth's air quality index estimates are consistent with NASA-Giovanni's satellite images of airborne particulates. The reasons for this reduction are the stringent enactment of laws and regulations, including the restriction of all external movements, the suspension of transport segments, the cessation of production units, marketplaces, workspaces, office buildings, educational institutions, and any other institutional places portrayed to combat the Corona affected areas. According to the research, pandemic incidences are more common in highly - populated metro cities. The AQI index has gone up in the post-pandemic period because of the resumption of all human activities in the area. A pandemic situation can be a blessing in disguise, but cannot sustain for a longer period. A multi-faceted approach can be adopted to control air pollution in Agra as the major pollution occurred due to significant industrial activities and vehicular emissions. The transport authority can introduce and promote electric buses and vehicles. Excessive traffic jams can cause major vehicular emissions. Strict penalties can be enforced on the vehicles ' – compliance with the AQI. Proper traffic management of the city can reduce the possibility of air pollution. Besides, the implementation of stricter emissions standards for vehicles and restriction of vehicle entry in green zones can be another preventive measure. The municipality has the scope to introduce more pedestrian zones and cycling paths near the tourist spots. The state government can also incentivize the use of electric and hybrid vehicles. The authorities must enforce strict emission control policies for the factories in and around the city. It is also advised to relocate highly polluting industries to the less populated areas in the district and introduce cleaner fuels and technologies in the industrial process. Green initiatives must be taken to protect the area by planting more trees and creating urban green spaces. It will increase the green cover of the polluted areas. There must be a green belt developed between the city and industrial zones. Dust from the construction sites must be controlled by using a “dust suppression system”. Frequently conducted awareness campaigns to educate people about the sources and effects of air pollution are one of the most preventive measures encouraging community participation in pollution control. The nation must take air pollution as a challenge, and should create pure atmospheric conditions like lockdown even in the neo-normal period. This is the only way through which we can maintain environmental sustainability in any most valued destination like Agra.

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