frontiers in Environmental Science

BRIEF RESEARCH REPORT
published: 14 January 2022
doi: 10.3389/fenvs.2021.784959

A Comparative Study of Particulate Matter Between New Delhi, India and Riyadh, Saudi Arabia During the COVID-19 Lockdown Period

Bhupendra Pratap Singh[1]*, Gaber E. Eldesoky[2], Pramod Kumar[3], Prakash Chandra[4], Md Ataul Islam[5] and Shakilur Rahman[6]

[1]Department of Environmental Studies, Deshbandhu College, University of Delhi, New Delhi, India, [2]Chemistry Department, College of Science, King Saud University, Riyadh, Saudi Arabia, [3]Department of Chemistry, Sri Aurobindo College, University of Delhi, New Delhi, India, [4]Department of Biotechnology, Delhi Technological University, New Delhi, India, [5]Division of Pharmacy and Optometry, School of Health Sciences, Faculty of Biology, Medicine, and Health, University of Manchester, Manchester, United Kingdom, [6]Department of Medical Elementology and Toxicology, School of Chemical and Life Sciences, Jamia Hamdard, New Delhi

OPEN ACCESS

Edited by:
Suvarna Sanjeev Fadnavis,
Indian Institute of Tropical
Meteorology (IITM), India

Reviewed by:
J. Abbas,
Shanghai Jiao Tong University, China
Rohini Bhawar,
Savitribai Phule Pune University, India

***Correspondence:**
Bhupendra Pratap Singh
bpsingh0783@gmail.com
0000-0002-0513-9082

Specialty section:
This article was submitted to
Atmosphere and Climate,
a section of the journal
Frontiers in Environmental Science

Received: 28 September 2021
Accepted: 27 December 2021
Published: 14 January 2022

Citation:
Singh BP, Eldesoky GE, Kumar P, Chandra P, Islam MA and Rahman S (2022) A Comparative Study of Particulate Matter Between New Delhi, India and Riyadh, Saudi Arabia During the COVID-19 Lockdown Period. Front. Environ. Sci. 9:784959. doi: 10.3389/fenvs.2021.784959

Novel Coronavirus disease (COVID-19), after being identified in late December 2019 in Wuhan city of China, spread very fast and has affected all the countries in the world. The impact of lockdowns on particulate matter during the lockdown period needs attention to explore the correlation between anthropogenic and natural emissions. The current study has demonstrated the changes in fine particulate matter $PM_{2.5}$, PM_{10} and their effect on air quality during the lockdown. The air quality before the lockdown was low in New Delhi (India) and Riyadh (Saudi Arabia), among major cities worldwide. The air quality of India is influenced by dust and sand from the desert and surrounding areas. Thus, the current study becomes important to analyse changes in the air quality of the Indian sub-continent as impacted by dust storms from long distances. The result indicated a significant reduction of $PM_{2.5}$ and PM_{10} from 93.24 to 37.89 μg/m^3 and from 176.55 to 98.87 μg/m^3 during the lockdown period as compared to pre lockdown period, respectively. The study shows that average concentrations of PM_{10} and $PM_{2.5}$ have declined by -44% and -59% during the lockdown period in Delhi. The average value of median PM_{10} was calculated at 33.71 μg/m^3 for Riyadh, which was lower than that value for New Delhi during the same period. The values of PM_{10} were different for pre and during the lockdown periods in Riyadh, indicating the considerable influence on air quality, especially the concentration of PM_{10}, from both the natural (sand and dust storms) and the anthropogenic sources during the lockdown periods. However, relatively smaller gains in the improvement of air quality in Riyadh were correlated to the imposition of milder lockdown and the predominance of natural factors over the anthropogenic factors there. The Air Quality Index (AQI) data for Delhi showed the air quality to be 'satisfactory' and in the green category during the lockdown period. This study attempts to better understand the impact of particulate matter on the short- and long-term air quality in Delhi during the lockdown. This study has the scope of being scaled up nationwide, and this might be helpful in formulation air pollution reduction and sustainable management policies in the future.

Keywords: COVID-19, air quality, particulate matter, New Delhi, Riyadh

INTRODUCTION

The COVID-19 originated from the city of Wuhan in China, supposedly in December 2019after the detection of the first COVID-19 positive case (Bashir et al., 2020; Chen et al., 2020). COVID-19 has become a pandemic impacting the entire population. Corona Virus causes respiratory infection in people and is known as SARS-CoV-2 (Zheng, 2020). The World Health Organisation (WHO) declared the Corona Virus outbreak a pandemic on March 11, 2020 (World Health Organisation, 2020).

Several studies have confirmed high transmissivity of the Corona Virus, which affects many people within a short period (Gautam and Trivedi, 2020; Sharma et al., 2020). As of October 04, 2021, more than 248 million people have been affected, and more than five million people have died across countries (including India) because of the COVID-19 virus (World metros, 2021; Ritchie et al., 2020). The effects of the COVID-19 pandemic went far beyond just health to economic, social, psychological, and occupational (Abbas et al., 2019; Mubeen et al., 2020; Liu et al., 2021a; Abbasi et al., 2021; Paulson et al., 2021; Wang et al., 2021). The pandemic has impacted the mental well-being of a huge proportion of the population in the form of distress, stress, and depression, as revealed by several studies (Abbas et al., 2019; Aqeel et al., 2021; Lebni et al., 2021; Local Burden of Disease, 2021). Su et al. (2021b) reported that COVID-19 induced unprecedented illness perception has caused mental disorders, including anxiety and depression, which have severely impacted individuals' mental health. Furthermore, a study reported the relationship between the COVID-19 infection and vaccine non-adopters in terms of detection of the number of new corona cases (Su et al., 2020). Several research scholars claimed that reduced stress and depression lead to better mental health (Li et al., 2021). Better social and educational support to vulnerable individuals might help explain differences in the scale of observed mental health problems across countries. (Azadi et al., 2021; Abbas., 2021; Su et al., 2021a; Azizi et al., 2021; Abbas et al., 2019).

India ranked third after the USA and Brazil among the top countries with more than 12 million cases and more than 0.16 million deaths (Ritchie et al., 2020; world metros, 2021). In India, the Ministry of Health and Family Welfare reported the first COVID-19 case in Kerala on 30th January, 2020 (Gutam and Hens, 2020), and the first death was reported on 12th March, 2020 (World Health Organisation, 2020b). On 22nd March, 2020, the Central Government imposed an emergency "Janata Curfew" in the whole country, which was intensified by a city-scale quarantine and nationwide lockdown starting from March 24, 2020 (Khetan et al., 2020).

Since then, more restrictive measures have been introduced except for essential services, such as fire, police, and health. Then industrial activities, hospital services, and educational institutions were also suspended until further notice. The government took these steps to flatten the infection curve. Since the lockdown meant the least movement and transportation and a considerable reduction in construction activities, the air quality improved quite significantly. Similar socio-economic activity restrictions were also seen in other countries in response to the pandemic (Kerimray et al., 2020). A drop in air pollutants has been recorded because of these initiatives (Dutheil et al., 2020).

India is considered one of the most severely polluted countries globally, especially for particulate matter and dust particles. The air quality in India is impacted by meteorological parameters such as winds which bring a huge quantity of dust and sand from the desert and surrounding areas (Knippertz et al., 2007; Pye, 2015; Albugami et al., 2019). Many studies have reported variations in aerosol loading (dust particle in the atmosphere), surface cooling, and their possible relationships with meteorological factors such as rainfall, wind speed in India and East Asia (Krishnan and Ramanathan, 2002; Devara et al., 2003; Cheng et al., 2005; Prasad et al., 2006; Nakajima, 2007; George et al., 2008). The air quality of the Indian subcontinent, including the north-western part of India, is possibly influenced by the dust storms which may originate from Arabian Peninsula.

This study tried to correlate the possible changes in the air quality of Delhi with the dust storms from Arabian Peninsula (Saudi Arabia). Dust storms are common in the north-western part of the Indian subcontinent, the Arabian Peninsula, China, and the Sahara Desert (Wang, 2015). The transport of dust particles originated from the Arabian Peninsula and enter India through Afghanistan, Pakistan via land routes and through the Arabian Sea via sea routes (Middleton, 1986; Kedia et al., 2018). In addition, dust storms can severely affect air quality and particulate matter concentrations ($PM_{2.5}$ and PM_{10}). A study suggested a significant positive correlation between precipitation and the increase of dust emissions, especially in Saudi Arabia, Oman, and the Thar Desert, India (Kaskaoutis et al., 2012; Namdari et al., 2018).

Several literatures reported that the frequency and the intensity of dust storms have been increasing, which is positively associated with land-use and land-cover changes and meteorological factors in some regions of the world like the Arabian Peninsula (Yu et al., 2015; Alobaidi et al., 2017; Gherboudj et al., 2017; Almazroui et al., 2018), and the Middle-East (Rashki et al., 2012; Türkeş, 2017; Namdari et al., 2018) as well as Central Asia (Indoitu et al., 2015; Xi and Sokolik 2015). Furthermore, a positive correlation between dust and meteorological factors is attributed to dust emission over Arabian Peninsula and its transportation to the Indian subcontinent (Jin et al., 2021). In addition, the Indian subcontinent, especially northern parts of India, is a potential source of pollution originating from the Thar desert located in northwestern India (Sarkar et al., 2019; Jin et al., 2021).

A sudden halt of all anthropogenic activities (mainly transportation and industrial activities) during the lockdown measures in India improved the air quality. Several studies conducted throughout the world reported an association between short term exposure to particulate matter and COVID-19 confirmed cases such as an outbreak in over major cities of Saudi Arabia (Farahat et al., 2021) Northern Italy (Bashir et al., 2020; Report et al., 2020), China (Mehmood et al., 2020; Wang et al., 2020a; Zhu et al., 2020), in Malaysia (Suhaimi et al., 2020) and a similar result for the United States (Wu et al., 2020).

Several studies have reported a significant improvement in air quality during the lockdown period (Gautam, 2020; Zhu et al., 2020) especially, Particulate Matter $PM_{2.5}$ (size <2.5 μm^3) and PM_{10} (size <10 μm^3), which are considered significant air pollutants directly associated with adverse health effects on human beings (Kumar et al., 2014a; Singh et al., 2014; Singh et al., 2021a). A study in China reported a positive association between short-term exposure to air pollution and coronavirus disease (Muhammad et al., 2020; Zhu et al., 2020). Another study in China also suggested a positive correlation between particulate matter ($PM_{2.5}$ and PM_{10}) and mortality rates of COVID-19 (Bashir et al., 2020). Another study from China has also shown that ambient temperature might play a crucial role in COVID-19 infection (Xie and Zhu, 2020). Several recent studies have highlighted a significant improvement in air quality with respect to reduction of $PM_{2.5}$ by 34–73.85%, of PM_{10} by 40–58%, (), of NO_2 by 3–79%, of CO by 2–60%, of NH_3 by 30–75%, (), and of SO_2 by 15–58% () in different cities across India during the lockdown period (Dutta & Jinsart, 2020; Kumari and Toshniwal, 2020; Navinya et al., 2020; Pant et al., 2020; Resmi et al., 2020; Vadrevu et al., 2020; Kumar et al., 2020; Kumar & Tyagi, 2021; Khan et al., 2021; Maji et al., 2021; Sathe et al., 2021).

Several studies have been conducted in different parts of cities to assess the impact of COVID-19 lockdown on air quality but for a short period of time (Kotnala et al., 2020 (January–March 2020); Kumar, 2020 (March–May 2020); Kumar et al., 2020 (March–April 2015–2020); Mahato et al., 2002 (3 March–14 April 2020); Navinya et al., 2020 (1 February–3 May 2019–2020); Srivastava et al., 2020 (1^{st}–20^{th} February and 24 March–14 April 2020). The present investigation was an attempt to evaluate the changes in the level of the particulate matter before and during the complete lockdown period (1 January–31^{th} May 2020)

Northwest Indian sub-continent faces the adverse impacts of dulust particles, including particulate matter from distant places like Saudi Arabia and meteorological parameters such as wind and precipitation. Both of these factors played a crucial role in the deterioration of the air quality in India. Therefore, the present investigation attempted to evaluate the changes in the level of the particulate matter before (January 1, 2020 to 23^{rd} March, 2020) and during the entire lockdown period (24^{th} March, 2020 to May 31, 2020) in Delhi India. Hence, the present study also aims to evaluate the levels of particulate matter in two different cities (New Delhi and Riyadh) during the lockdown period (1st January to May 31, 2020). Further, the study compared the concentration of particulate matter for pre-lockdown and during the lockdown periods and explored the potential natural and anthropogenic emission sources.

Further, the study aims to increase the scientific rigor of research in this area. However, some of the limitations of the current manuscript required access to meteorological parameters, including rainfall, relative humidity, solar radiation, and wind speed. These limitations can be tackled in future studies with larger sample sizes and the inclusion of more factors in the analysis to draw exciting results.

MATERIALS AND METHODS

To investigate the effect of restricted mobility on the concentration levels of particulate matter in the ambient atmosphere of Delhi (India) and Riyadh (Saudi Arabia), we utilized the air quality index (AQI) data from the respective Air Quality Monitoring Stations. The pandemic situation was classified into two periods, before lockdown and during lockdown for both the cities (Delhi and Riyadh). The time for Delhi, India before lockdown (between 1^{st} January, 2020, and 24^{th} March, 2020) was termed as 'pre-lockdown' period, and the time between 25^{th} March and May 31, 2020 was termed as 'during-lockdown' period. The time for Riyadh, Saudi Arabia before lockdown (between January 2020, and March 2020) was termed as "pre-lockdown" period, and the time between March and May 2020 was termed as 'during-lockdown' period. So, in the current study authors have studied and compared the air quality in both these cities in a comparable time frame.

Data and Sources

The hourly and daily data on air pollutants were obtained from the online portal of the Central Pollution Control Board (CPCB), particularly the data for PM_{10} (size of particulate matter <10 microns), $PM_{2.5}$ (size of particulate matter <2.5 microns), and meteorological parameters. In this paper, we focused and collected secondary data for only PM_{10} and $PM_{2.5}$ from 1^{st} January, to 31^{st} May, 2020 to determine the relative changes (in %) in air quality from the CPCB monitoring site (https://app.cpcbccr.com/ccr/#/caaqm-dashboard-all/caaqm-landing). In addition, the data on PM_{10} for Riyadh, Saudi Arabiawere procured from the World Air Quality Index from 1^{st} January to April 10, 2020 (https://aqicn.org/data-platform/covid19/). CPCB in India provides high-quality data through rigorous quality assurance or quality control (QA/QC) programs via scientific sampling, analysis, and calibration (Mahato et al., 2002).

Air Quality Index (AQI) is a tool for identifying the pollutant criteria and is also used to report the severity of air pollution to the public. In addition, AQI plays an important role in deliberating an individual pollutant into a whole index using the aggregation method (Ott, 1978).

AQI India provides air pollution data with a real-time Air Quality Index for various air pollutants. The National Ambient Air Quality Standard (NAAQS) revised AQI by considering eight parameters, namely, PM_{10}, $PM_{2.5}$, NO_2, SO_2, CO, O_3, NH_3, and

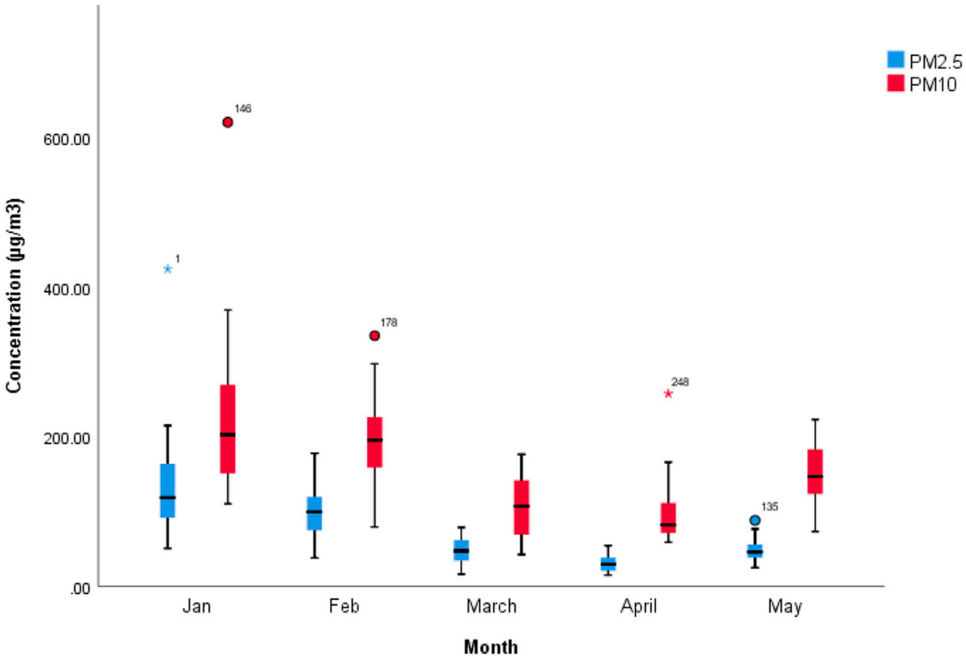

FIGURE 1 | The box plot for concentration of $PM_{2.5}$ and PM_{10} during the pandemic, North Campus Delhi University.

Pb for a short term (up to 24 hourly average) period (Kumar et al., 2014b; CPCB, 2016). An AQI is used to provide information about the quality of air in terms of pollution level. It is directly associated with public health. The public health risk increases with an increase in the AQI level. Six AQI categories have been defined for health risk, namely, "Good", "Satisfactory", "Moderately polluted", "Poor", "Very Poor", and "Severe".

Further, this index provides information to the public who are sensitive to air pollution (Beig et al., 2010). To identify the overall improvement in air quality over Delhi, AQI was calculated, and details of AQI are available elsewhere (Sharma et al., 2020). The AQI is divided into five categories: good (0–50), satisfactory (51–100), moderate (101–200), poor (201–300), very poor (301–400), and severe (401–500) respectively. AQI method that provides sub-index approach using six criteria pollutants (i.e. PM_{10}, $PM_{2.5}$, SO_2, NO_2 CO and O_3) were converted into AQI standard value. The AQI for each pollutant was calculated by the following formula given by Sahu & Kota (2017).

$$AQIi = \frac{\text{IHI} - \text{ILO}}{\text{BreakHI} - \text{BreakLO}}\, x\ (\text{Ci} - \text{BreakLO}) + \text{ILO}$$

where C_i is the observed concentration of the pollutant "i"; $Break_{HI}$ and $Break_{LO}$ are breakpoint concentrations, greater and smaller to C_i; and I_{HI} and I_{LO} are corresponding AQI ranges.

For the final calculation of AQI for individual pollutants, at least a minimum of three pollutants for the AQI value is required. In this study, we have also considered the daily average values of other pollutants (NO_X and O_3) to calculate AQI values. The formula for calculating the AQI value was presented in the **Supplementary File**. The AQI values for particulate matter ($PM_{2.5}$ and PM_{10}) before and during lockdown were calculated corresponding to the other pollutants.

Data Analysis and Procedure

The present study analyzed the total data ($n = 152$ and $n = 90$) for a monitoring station, North Campus, Delhi University, New Delhi, and Riyadh, Saudi Arabia, to evaluate the variable changes in particulate matter in the comparative time frame. Time series plotting techniques were used to investigate variable changes over time during the pre and lockdown period. Statistical Package for the Social Sciences (SPSS) software was used to perform the statistical analysis (version 26.0 SPSS Inc., Chicago, IL, United States). The wind rose plot was drawn using Lake Environment software with wind speed input parameters.

RESULTS AND DISCUSSION

$PM_{2.5}$ and PM_{10} Levels in New Delhi, India

In the present paper, particulate matter ($PM_{2.5}$ and PM_{10}) levels have shown a significant decline from January to May 2020 during the pandemic situation (**Figure 1**). According to Singh & Kumar (2021) the continuous reduction in the levels of particulate matter ($PM_{2.5}$ and PM_{10}) was observed in subsequent months during the complete lockdown caused by the restriction of non-essential services such as transport and complete closure of markets and industrial activities. Average concentrations of $PM_{2.5}$ and PM_{10} were 123.24 µgm-^{3} and 151.24 µgm-^{3,} respectively, in North Campus, Delhi University. The maximum concentrations of $PM_{2.5}$ and PM_{10} were

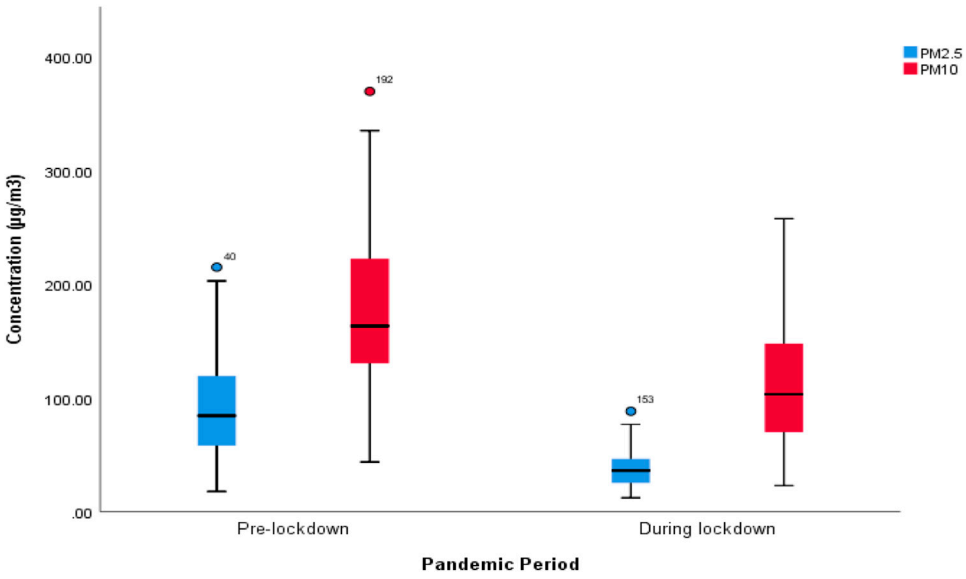

FIGURE 2 | The box plot for concentration of $PM_{2.5}$ and PM_{10} during pre- and during the lockdown period, North Campus Delhi University.

178.2 µgm^{-3} and 335.43 µgm^{-3} respectively during the month of February, whereas the minimum were 12.36 µgm^{-3} and 23.06 µgm^{-3} during the month of May. In addition, the lowest mean concentrations were 31.42 µgm^{-3} and 100.16 µgm$^{-3,}$ respectively, during the month of April (**Supplementary Figure S1**). Thus, the concentration of $PM_{2.5}$ was observed far below the prescribed standard value of CPCB (40 µgm^{-3}) in the month of April. The significant reduction in $PM_{2.5/10}$ was caused by restrictions on the use of private vehicles and other non-essential transportation, halt on construction and industrial activities. This led to a general reduction of anthropogenic PM pollution (Klimont et al., 2017). The linear decline in the average concentration of $PM_{2.5}$ was reported even in New York (µgm^{-3}) from December 2019 to March 2020 (Chauhan and Singh 2020). Singh et al. (2021b) claimed that the mean concentrations of $PM_{2.5}$ and PM_{10} were slightly higher during the month of May owing to the start of use of necessary transportation and controlled industrial activities in non-containment zones in Delhi. (**Supplementary figure S2**).

The present study focused on determining drastic changes in the concentrations of air pollutants, especially particulate matter $PM_{2.5}$ and PM_{10} concentrations, during the pandemic situation in India, including Delhi. The $PM_{2.5}$ and PM_{10} concentrations significantly declined from January 2020 to May 2020 during the pandemic situation in Delhi. A constant decline in the $PM_{2.5}$ and PM_{10} concentrations was observed in subsequent months due to complete lockdown, during which international and trains, traffic activities, markets, and industrial activities were suspended. The average concentrations of $PM_{2.5}$ and PM_{10} in the pre-lockdown period were observed to be 93.24 µgm^{-3} and 176.55 µgm$^{-3,}$ whereas, during the lockdown period, they were 36.09 µgm^{-3} and 98.87 µgm^{-3}, respectively (**Figure 2**). Several recent studies on Delhi reported similar results for PM2.5 concentration values; Singh et al., 2021 (41.41 µgm-3), Dutta and Jinsart, 2020 (42.15 µgm-3), Chaudhary et al., (33.09–122.2 µgm-3), Roy and Balling (46.5–39.1 µgm-3). This significant reduction was mainly attributable to government's orders on non-use of private vehicles and other non-essential transportation since transport sector is the primary source of particulate matter in the atmosphere.

The maximum value of $PM_{2.5}$ and PM_{10} in the pre-lockdown period was calculated to be 215.5 µgm^{-3} and 369.94 µgm^{-3} whereas, during the lockdown period, it was estimated to be 88.5 µgm^{-3} and 93.24 µgm^{-3} respectively during the month of April. In terms of minimum concentrations of $PM_{2.5}$ and PM_{10}, pre-lockdown values were recorded to be 17.84 µgm^{-3} and 43.82 µgm^{-3} respectively during the month of March; whereas, during the lockdown period, these respective values were 12.36 µgm^{-3} and 23.03 µgm^{-3} during the month of April (**Supplementary Figure S3**). The present study shows that average concentrations of $PM_{2.5}$ and PM_{10} declined by -59% and -44%, respectively, during the lockdown period in Delhi.

According to Kerimra, spatial reduction in the value of $PM_{2.5}$ varied between 6 and 34% during the lockdown period in Almaty, Kazakhstan (Kerimray et al., 2020). A study conducted in Zaragoza, Spain, also reported a decline in the concentration of $PM_{2.5}$ by -58% during March 2020 compared with February 2020. Similar changes were also observed in Beijing and other cities of China during the lockdown period (Sharma et al., 2020). Another study found a reduction in the concentration of PM_{10} in urban areas and traffic areas by -27.8% and -31%, respectively, in Barcelona (Spain) during their lockdown periods (Tobias et al., 2020). Thus, the significant reduction in the concentration of $PM_{2.5}$ and PM_{10} during the lockdown period could also be attributed to a lower frequency of temperature inversion, atmospheric temperature, increasing wind speeds, and changes in wind direction.

TABLE 1 | Several recent studies across the world during the lockdown period.

The study area (city, country)	Key findings for $PM_{2.5}$ and PM_{10}	Author (year)
Present Study (Delhi, India)	Average concentrations for $PM_{2.5}$ and PM_{10} during the lockdown period were observed to be 36.09 μg/m^3 and 98.87 μg/m^3, respectively	Present Study
Delhi (India)	Average concentrations for $PM_{2.5}$ and PM_{10} were varied from 41.14 to 60.56 μg/m^3 and 86.81–169.32 μg/m^3 for different lockdowns in Delhi, India, respectively.	Singh & Kumar (2021)
Delhi (India)	Reductions in $PM_{2.5}$ (39%) and PM_{10} (60%) as compared to 2019.	Mahato et al. (2002)
Delhi (India)	A similar study conducted in Delhi, the result showed that $PM_{2.5}$ and PM_{10} levels declined up to 55–65% during the lockdown period	Garg et al. (2021)
Delhi (India)	The average concentrations of atmospheric air pollutants $PM_{2.5}$ and PM_{10} were reduced to 42.15 μg/m^3, and 128.68 μg/m^3 and where 73.85%, and 46.48% lower than pre-COVID-19 levels.	Dutta & Jinsart (2020)
Chennai (India)	overall $PM_{2.5}$ values decreased for the lockdown (ranging from ~32–187%), weekly analysis shows the variation in reduction/increase.	Singh and Tyagi (2020)
Uttar Pradesh (India)	A significant reduction in the ground-level pollution load of $PM_{2.5}$ and PM_{10} has been observed during the lockdown period in Uttar Pradesh.	Kumar (2021)
Uttar Pradesh and the Delhi-National Capital Region (India)	The $PM_{2.5}$ concentrations during lockdown Phase 1 were approximately 44.6% lower for cities in Uttar Pradesh and about 58.5% lower for the Delhi-NCR	Goel et al. (2020)
Delhi, Mumbai, Kolkata, Chennai, and Hyderabad (India)	The average concentration levels of $PM_{2.5}$ and PM_{10} have decreased nationwide by 33%, and 34% respectively during the nationwide lockdown compared to their concentration levels before the lockdown.	Verma and Kamyotra (2021)
Delhi, Mumbai, Kolkata, and Bangalore (India)	Concentration declined in $PM_{2.5}$ (~41%) and PM10 (52%).	Jain & Sharma, (2020)
Delhi, Mumbai, Kolkata, and Chennai (India)	The findings conclude a significant improvement in air quality with respect to a reduction of 49–73%, 17–63%, in the mean concentration of $PM_{2.5}$ and PM_{10}, respectively.	Pant et al. (2020)
India (22 different cites)	Reduction in concentration for $PM_{2.5}$ (43%) and PM_{10} (31%)	Sharma et al. (2020)
Dwarka river basin within Jharkhand and West Bengal (India)	PM_{10} concentration was reduced from 189-278 μg/m^3in the pre-lockdown period to 50–60 μg/m^3.	Mandal & Pal (2020)
Lucknow, and New Delhi, (India)	$PM_{2.5}$ concentration for Lucknow and New Delhi declined from 54–222 and 47–204 μg/m^3 during the lockdown period (25th March to 14 April, respectively.	Srivastava et al. (2020)
Gujarat (India)	The concentrations of $PM_{2.5}$ and PM_{10} were reduced by 38–78%, and 32–80%, in Gujarat respectively.	Selvam et al. (2020)
Mecca, Madinah, and Jeddah (Saudi Arabia)	No major changes in PM_{10} were observed, whereas other findings were 44% reduction in NO_2 and 16% reduction in CO concentrations during COVID-19 restrictions.	Farahat et al. (2020)
Makkha city (Saudi Arabia)	Findings indicate the presence of a significant decrease of concentration rates during the lockdown period, compared with the pre-pandemic period, by 26.34% for SO_2, 28.99% for NO_2, 26.24% for CO, 11.62% for O_3, and 30.03% for PM_{10}.	Morsy et al. (2020)
Riyadh, Makkha, and Jeddah (Saudi Arabia)	The percentage changes in concentrations of CO (33.60%) and SO_2 (44.16%) were higher in Jeddah; PM_{10} (91.12%) in Riyadh, while NO_2 (44.35%) and O_3 (18.98%) were highest in Makkah	Aljahdali et al. (2021)
Eastern Province (Saudi Arabia)	The Eastern Province, Saudi Arabia experienced significant concentration reductions at varying rates for PM_{10} (21–70%), CO (5.8–55%), and SO_2 (8.7–30%), while O_3 concentrations showed increasing rates ranging between 6.3 and 45%.	Anil & Alagha (2020)
Riyadh (Saudi Arabia)	After sandstorm, the air pollutants, CO level increased by 84.25%; $PM_{2.5}$: 76. 71%; O_3: 40.41%; NO_2: 12.03%; and SARS-CoV-2 cases increased by 33. 87%. However, the number of deaths decreased by 22.39%.	(Meo, 2021)
Global countries (34 countries including Saudi Arabia)	On a global average basis, a 34.0% reduction in NO_2 concentration and a 15.0% reduction in $PM_{2.5}$ were estimated during the strict lockdown period (until April 30, 2020). Global average O_3 concentration increased by 86.0% during this same period.	Torkmahalleh et al. (2020)
Cairo, Egypt and Riyadh (Saudi Arabia)	The results demonstrated that the lockdown was associated with a reduction in NO_2 by 40.3 and 23% in Riyadh and Cairo, respectively.	Abdelsattar et al. (2021)
China and Europe (France, Germany, Spain, and Italy)	Decreased $PM_{2.5}$ in 367 cities (18.9 μg/m3), and Wuhan (-1.4 μg/m3)	Zambrano-Monserrate et al. (2020)
New York, Los Angeles, Zaragoza, Rome, Dubai, Delhi, Mumbai, Beijing, and Shanghai	Declined $PM_{2.5}$ concentration in Delhi (35%), Mumbai (14%), Beijing (50%), Shanghai (50%), Dubai (11%), New York (32%), Los Angeles (4%), and Zaragoza and Rome (no changes).	Chauhan & Singh (2020)

(Continued on following page)

TABLE 1 | (*Continued*) Several recent studies across the world during the lockdown period.

The study area (city, country)	Key findings for $PM_{2.5}$ and PM_{10}	Author (year)
Spain (Barcelona)	Decline PM_{10} concentration in Spain from -28% to -31%.	Tobias et al. (2020)
Malaysia and Southeast Asia	Reduced concentration in PM_{10} for (industrial: 28–39%, urban: 26–31%), and $PM_{2.5}$ (industrial: 20–42%, urban: 23–32%) respectively.	Kanniah et al. (2020)
Southern European cities (Nice, Rome, Valencia and Turin) and Wuhan (China)	Declined in $PM_{2.5}$ and PM_{10} (~8% in Europe and ~42% in Wuhan) at urban stations, respectively.	Sicard et al. (2020)
Yangtze River Delta Region (China)	Reductions in $PM_{2.5}$ (27–46%) in China.	Li et al. (2020)
44 cities in northern China	The AQI for $PM_{2.5}$, and PM_{10}, decreased by 6.76%, and 5.93%, respectively.	Bao & Zhang, (2020)
Almaty (Kazakhstan)	Reduction in $PM_{2.5}$ (21%, spatial variations: 6–34%).	Kerimray et al. (2020)
Northern China	Reduction in $PM_{2.5}$ (29 ± 22%), and (31 ± 6%) in Northern China and Wuhan respectively.	Shi & Brasseur (2020)
Sale City (Morocco)	PM_{10} was reduced by 75% in Sale City.	Otmani et al. (2020)
China (Beijing, Shanghai, Guangzhou, and Wuhan)	Decreased $PM_{2.5}$ in Beijing, Shanghai, Guangzhou, and Wuhan by 9.23, 6.37, 5.35, and 30.79 μg/m^3, respectively.	Wang et al. (2020b)

Role of Meteorological Parameters

The meteorological parameters such as temperature, mixing height, wind speed, and rainfall played a significant role in changing $PM_{2.5}$ and PM_{10} levels during the lockdown period. $PM_{2.5}$ and PM_{10} levels were observed to rise in the second week of phase-I of lockdown, primarily attributed to changes in meteorological conditions over Delhi and NCR.

Due to the onset of summers, the temperature started to increase with an average temperature of 20.9 °C on March 16, 2020 to 30.4 oC on 1st May 2020, leading to dry and dusty conditions. Moreover, it was reported that a mild dust storm from the western part of the country and even from the gulf regions hit Delhi on 14th–15th April 2020, thus rapidly increasing the PM_{10} levels in Delhi and NCR. It is important to mention here that meteorological factors with average mixing height and wind speed improved the level of $PM_{2.5}$ and PM_{10} for pre-lockdown and lockdown phases against the same periods in the previous year. Wind speed and mixing height were also higher in the first lockdown phase than pre-lockdown levels. Spells of light to moderate rains were also recorded in Delhi NCR on 5th March, 14th March, 27th March, 28th—29th March, 17th, and 18th April, 25th and 26th April, and 3rd May during 2020, assisting in air quality improvement (CPCB, 2020).

The salient findings from several recent studies worldwide, including India and Saudi Arabia, during the lockdown period are presented in **Table 1**. A negative correlation between concentrations of $PM_{2.5}$, $PM_{10,}$ and ambient temperature was reported during the lockdown period, which indicated vertical dispersion of PM pollutants caused by high temperature (Singh et al., 2016; Singh et al., 2021c). The present study revealed a significant negative correlation between wind speed and particulate matter pollutants which possibly indicated the predominance of local sources as well as transportation of dust particles from longer distances over Delhi during the pre-lockdown period (**Supplementary Table S1**). The wind rose for Delhi during the lockdown period was depicted in the **Figure 3**. The wind rose blow from north-east much of the time during the lockdown period. This westerly wind and rainfall along the Mediterranean Sea could play a possible role in washing out the particulate matter during March, which led to further decline of the PM pollutant from the ambient atmosphere (Singh & Kumar, 2021).

PM_{10} Levels in Riyad, Saudi Arabia

The maximum and minimum median values in Riyadh were 245 μgm$^{-3,}$ and 6.0 μgm$^{-3,}$ respectively, during the same period. The average median of PM_{10} during the lockdown period was 33.71 μgm^{-3}. A similar result for Riyadh was reported (24.10 ± 4.78 μgm^{-3}) during the lockdown period by Aljahdali et al., 2021. The value of PM_{10} was observed much lower than the standard value (80 μgm^{-3} annual means) by prescribed Presidency of Meteorology and Environment (PME) (Munir et al., 2016).

The present study finds no major changes in particulate matter pre- and post-lockdown periods in Riyad, Saudi Arabia, which could be due to frequent dust events during the same period. Farahat also suggested similar findings over major cities (Mecca, Jeddah, Madinah) of Saudi Arabia during the Hajj Period of 2019–2020, where the winds played a crucial role in the transportation of dust (Farahat et al., 2021). Another study conducted in the Eastern Province of Saudi Arabia experienced a significant reduction in the concentration of PM_{10} (21–70%) during the lockdown period (Anil & Alagha, 2020). Morsy indicated a considerable decrease in concentration levels during the lockdown period, compared with the pre-pandemic period, by 30.3% for PM_{10} in Makkah city, Saudi Arabia (Morsy et al., 2021). The flatted peak of PM_{10} during the pandemic lockdown period was interpreted by the commitment of Makkah residents due to precautionary measures of COVID-19.

Furthermore, preventive measures such as curfew enforcement had contributed to lowering the level of particulate matter to a great extent in the capital of Riyadh. The complete lockdown and restricted industrial activities and vehicular movement resulted in a significant reduction in air pollutants, as recorded by some air quality monitoring stations located throughout the city (Saudi Gazette, 2020). A comparative graph between New Delhi (India) and Riyadh (Saudi Arabia) for particulate matter has been presented in **Figure 4** during the pandemic lockdown periods.

Air Quality Index

Delhi is considered as one of the most polluted cities on the Earth, with transport (41%), industry (18.61%), power plants (4.92%),

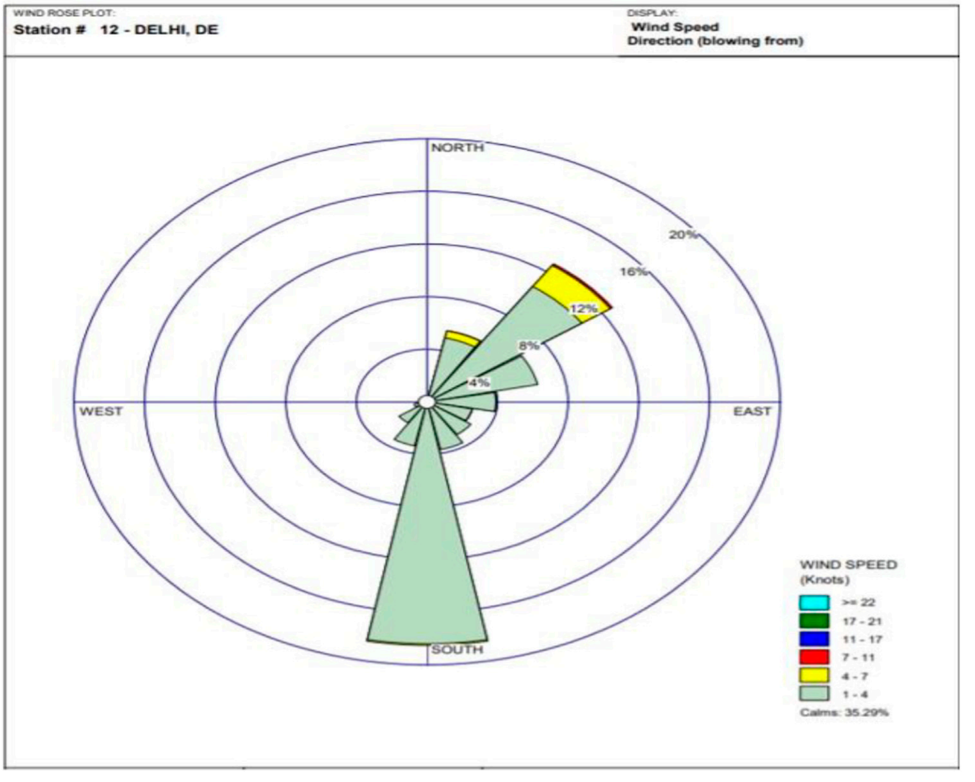

FIGURE 3 | Wind rose diagram for Delhi monitoring station.

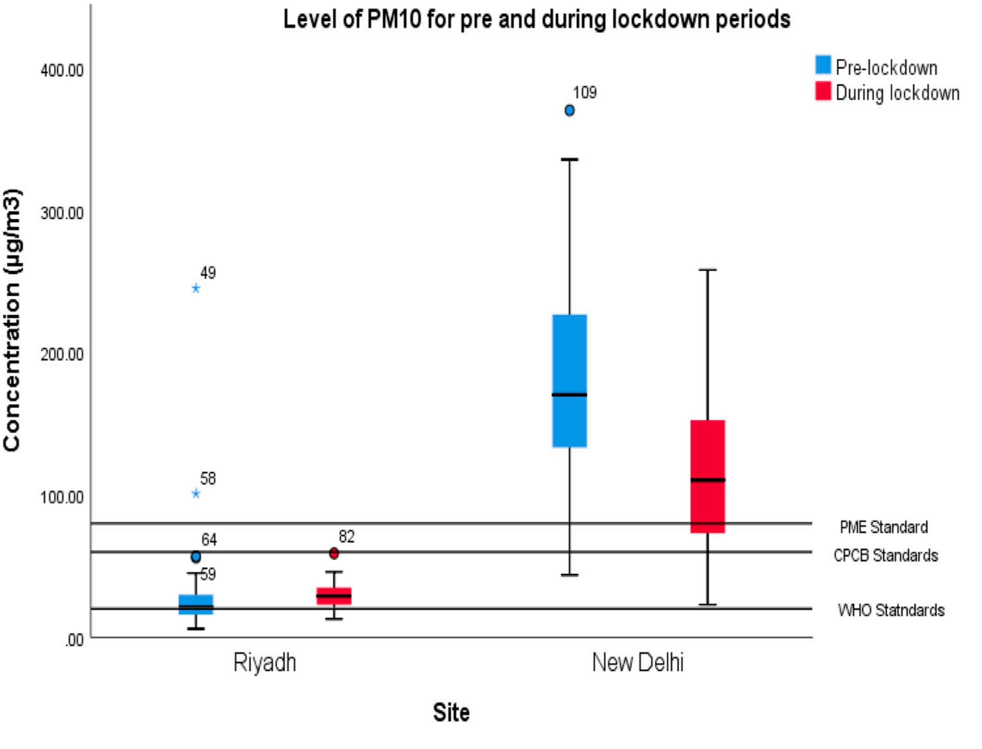

FIGURE 4 | Comparative study of PM_{10} for Riyadh and New Delhi during the pandemic periods.

TABLE 2 | National AQI classes, range, health impacts and health breakpoints for the seven pollutants (Scale: 0–500).

AQI category (range)	Associated Heath Impacts	$PM_{10}PM_{2.5}$ 24-h	24-h	Pre-lockdown $PM_{10}PM_{2.5}$ 24-h	Pre-lockdown PM_{10}24-h	During lockdown $PM_{2.5}$ 24-h	During lockdown 24-h
Good (0–50)	Minimal Impact	0–50	0–50				
Satisfactory (51–100)	Minor breathing discomfort to sensitive people	31–60	51–100			58	**99**
Moderately Polluted (101–200)	Breathing discomfort to the people with lung disease	61–90	101–250		151		
Poor (201–300)	Breathing discomfort to the people with prolonged exposure	91–120	251–350				
Very Poor (301–400)	Breathing illness to the people with prolonged exposure	121–250	251–430	211			
Sever (401–500)	Respiratory effects even on healthy people	250+	430+				

and residential emissions (2.96%) being the major contributing factors. The levels of $PM_{2.5}$ and PM_{10} in Delhi drastically declined during the pandemic. The AQI data for the present study shows that the mean concentrations of $PM_{2.5}$ and PM_{10} in the pre-lockdown period were 93.24 µgm-3 (indicating 'poor' air quality) 176.55 μgm^{-3} (indicating "moderately polluted" air quality) respectively. The average values of $PM_{2.5}$ and PM_{10} during the lockdown period were found to be 37.89 μgm^{-3} and 98.87 μgm^{-3} respectively, indicating a "satisfactory" green category of air quality equivalent to a few of the European cities during the lockdown period (**Table 2**). The drastic change in Delhi's air quality could be attributed to a decrease in socio-economic activities in the city. The concentrations of $PM_{2.5}$ and PM_{10} decreased by 59 and 44% during the lockdown period: a marked improvement in air quality. A similar finding was reported with a maximum reduction of 49% in AQI value in Delhi (Sharma et al., 2020). This led to a drastic improvement of the AQI values in Delhi. The air quality levels drastically improved because of the complete absence of major sources of primary air pollutants, such as emissions from vehicles, industry, construction, and brick kilns, during the lockdown period.

Apart from this, another study focused on exploring adverse effects on global public health and social media's indispensable role in providing the correct information in the COVID-19 health crisis (NeJhaddadgar et al., 2020; Liu et al., 2021b). A study claimed that human–pathogen interactions, such as data from Unit 731, can help epidemiologists better understand pandemics of COVID-19's scale (Su et al., 2021a; Su et al., 2021b).

CONCLUSION

The outcome of lockdown on air quality was assessed from 1st January, 2020 to 31st May, 2020 for New Delhi (India) and from 1st January, 2020 to 10th April, 2020 for Riyadh (Saudi Arabia). The significant reduction in the concentration levels of $PM_{2.5}$ and PM_{10} was caused by restrictions on the usage of private vehicles, suspension of non-essential transportation, construction, and industrial activities during the pandemic. The reduction in the concentration value of $PM_{2.5}$ was calculated to be more than the value of PM_{10} during the lockdown period, which indicates that traffic was a significant source for the emission of $PM_{2.5}$. Average concentrations of $PM_{2.5}$ and PM_{10} were calculated to be 123.24 $\mu g/m^3$ and 151.24 $\mu g/m^{3,}$ respectively, in North Campus, Delhi University. Average concentrations of $PM_{2.5}$ and PM_{10} in the pre-lockdown period were observed to be 93.24 $\mu g/m^3$ and 176.55 $\mu g/m^3$, respectively, whereas, during the lockdown period, their respective concentrations were 37.89 $\mu g/m^3$ and 98.87 $\mu g/m^3$. The values of PM_{10} showed different trends in Riyadh compared to New Delhi, indicating significant influence from natural (sand and dust storms) and anthropogenic sources during the lockdown periods. This could be attributed to no major changes for particulate matter for pre- and during the lockdown periods. The COVID-19 provided a rare opportunity to countries, including India, to collect air pollution baseline data during the nationwide lockdown. Air pollutants from transport, industries, and commercial activities were reduced significantly during this period. This baseline data could be very relevant to air pollution reduction policies.

Despite this, there are several challenges in the present study, particularly in selecting only one monitoring station. This is a small-scale study with a limited number of sites, which shows significant results. A detailed analysis with a greater number of monitoring stations is desirable. Identification of the sources of air pollution may be incomplete, and certain temporal aspects need to be further studied. In addition, meteorological parameters play a significant role in the transmission of COVID-19 that need to be examined in detail. The non-enforcement of India's anti-pollution laws is one of the major factors contributing to the high pollution load in India. More research emphasizing these areas is needed. The government should make efforts to maintain positive air quality by instituting advanced emission control technologies because it can significantly improve the environment and thus the health of the people.

The relationship between the air quality and COVID-19 induced lockdowns is significant, subject to the strength of local meteorological and other natural factors. For example, the magnitude of improvement in the air quality in Delhi, shown by a drastic reduction in the concentration of air pollutants, especially $PM_{2.5}$ and PM_{10}, is mainly correlated with the on-ground implementation of the lockdown and prevalence of support local factors, including meteorological factors like wind speed etc. However, relatively smaller gains in the improvement of air quality in Riyadh are correlated to the imposition of milder lockdown and the predominance of natural factors over the anthropogenic factors there.

The paper conveys the positive impact of lockdowns on air quality in metropolitan cities. The gains are subject to many factors, two of which have been established in the current study in the form of the intensity of lockdown and prevalence and relative strength of local meteorological and natural factors against their anthropogenic counterparts.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/**Supplementary Material**, further inquiries can be directed to the corresponding author.

AUTHOR CONTRIBUTIONS

BS: Conceptualization, introduction analysis, methodology section. GE: Analysis of the result and discussion for particulate matter for Saudi Arabia. PK: Framing the fine particulate matter associated with New Delhi. PC: Conceptualise the Air Quality Index of the current manuscript. MI improves the quality of the current draft, Writing review and editing. SR: Preparing a literature review and table for a comparative study between New Delhi India and Riyadh, Saudi Arabia

ACKNOWLEDGMENTS

The authors are grateful to the Researchers Supporting Project No. (RSP-2021/161). King Saud University, Riyadh, Saudi Arabia. The first author thanks Ms. Sonia Kumari and Dr. Sadaf Nazneen for insightful discussion and valuable suggestions during the preparation of the paper. The authors also appreciate Ms. Pallvi Rana, Ms. Nishtha Mittal, and Ms. Pooja deep proofreading the current manuscript.

SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fenvs.2021.784959/full#supplementary-material

REFERENCES

Abbas, J., Aman, J., Nurunnabi, M., and Bano, S. (2019). The Impact of Social media on Learning Behavior for Sustainable Education: Evidence of Students from Selected Universities in Pakistan. *Sustainability* 11 (6), 1683. doi:10.3390/su11061683

Abbas, J. (2021). Crisis Management, Transnational Healthcare Challenges and Opportunities: The Intersection of COVID-19 Pandemic and Global Mental Health. *Res. Globalization* 3, 100037. doi:10.1016/j.resglo.2021.100037

Abbasi, K. R., Abbas, J., and Tufail, M. (2021). Revisiting Electricity Consumption, price, and Real GDP: A Modified Sectoral Level Analysis from Pakistan. *Energy Policy* 149, 112087. doi:10.1016/j.enpol.2020.112087

Abdelsattar, A. S., Dawoud, A., Makky, S., Nafoal, R., Aziz, R. K., and El-Shibiny, A. (2021). Bacteriophages: From Isolation to Application. *Current Pharmaceutical Biotechnology*.

Albugami, S., Palmer, S., Cinnamon, J., and Meersmans, J. (2019). Spatial and Temporal Variations in the Incidence of Dust Storms in Saudi Arabia Revealed from *In Situ* Observations. *Geosciences* 9, 162. doi:10.3390/geosciences9040162

Aljahdali, M. O., Alhassan, A. B., and Zhang, Z. (2021). Environmental Factors Causing Stress in *Avicennia marina* Mangrove in Rabigh Lagoon Along the Red Sea: Based on a Multi-Approach Study. *Frontiers in Marine Science*.

Almazroui, M., Alobaidi, M., Saeed, S., Mashat, A., and Assiri, M. (2018). The Possible Impact of the Circumglobal Wave Train on the Wet Season Dust Storm Activity over the Northern Arabian Peninsula. *Clim. Dyn.* 50, 2257–2268. doi:10.1007/s00382-017-3747-1

Alobaidi, M., Almazroui, M., Mashat, A., and Jones, P. D. (2017). Arabian Peninsula Wet Season Dust Storm Distribution: Regionalization and Trends Analysis (1983-2013). *Int. J. Climatol.* 37, 1356–1373. doi:10.1002/joc.4782

Anil, I, and Alagha, O. (2020). Source Apportionment of Ambient Black Carbon During the COVID-19 Lockdown. *Int. J. Environ. Res. Public Health* 17 (23), 9021.

Aqeel, M., et al. (2021). The Influence of Illness Perception, Anxiety and Depression Disorders on Students Mental Health during COVID-19 Outbreak in Pakistan: A Web-Based Cross- Sectional Survey. *Int. J. Hum. Rights Healthc.* 14. doi:10.1108/ijhrh-10-2020-0095

Azadi, N. A., Ziapour, A., Lebni, J. Y., Irandoost, S. F., Abbas, J., and Chaboksavar, F. (2021). May 5)The Effect of Education Based on Health Belief Model on Promoting Preventive Behaviors of Hypertensive Disease in Staff of the Iran University of Medical Sciences. *Arch. Public Health* 79 (1), 69. doi:10.1186/s13690-021-00594-4

Azizi, M. R., Atlasi, R., Ziapour, A., Abbas, J., and Naemi, R. (2021). Innovative Human Resource Management Strategies during the COVID-19 Pandemic: A Systematic Narrative Review Approach. *Heliyon* 7 (12), e07233. doi:10.1016/j.heliyon.2021.e07233

Bashir, M. F., Ma, B. J., Bilal, B., Komal, B., Bashir, M. A., Farooq, T. H., et al. (2020). Correlation between Environmental Pollution Indicators and COVID-19 Pandemic: A Brief Study in Californian Context. *Environ. Res.* 187, 109652. doi:10.1016/j.envres.2020.109652

Beig, G., Ghude, S. D., and Deshpande, A. (2010). *Scientific Evaluation of Air Quality Standards and Defining Air Quality index for India*. Pune, India: Pune: Indian Institute of Tropical Meteorology, Ministry of Earth Science Government of India.

Chauhan, A., and Singh, R. P. (2020). Decline in PM2.5 Concentrations over Major Cities Around the World Associated with COVID-19. *Environ. Res.* 187, 109634. doi:10.1016/j.envres.2020.109634

Chen, K., Wang, M., Huang, C., Kinney, P. L., and Anastas, P. T. (2020). Air Pollution Reduction and Mortality Benefit during the COVID-19 Outbreak in China. *Lancet Planet. Health* 4 (6), e210–212. doi:10.1016/S2542-5196(20)30107-8

Cheng, Y., Lohmann, U., Zhang, J., Luo, Y., Liu, Z., and Lesins, G. (2005). Contribution of Changes in Sea Surface Temperature and Aerosol Loading to the Decreasing Precipitation Trend in Southern China. *J. Clim.* 18, 1381–1390. doi:10.1175/jcli3341.1

Cpcb (2020). *Central Pollution Control Board (CPCB), Ministry of Environment, Forest and Climate Change*. New Delhi: Government of India. https://app.cpcbccr.com/ccr/#/caaqm-dashboard-all/caaqm-landing.

Cpcb (2016). *NAQI Status of Indian Cities in 2015–16. Central Pollution Control Board (CPCB)*. New Delhi: Ministry of Environment, Forest and Climate Change, Government of India.

Devara, P. C. S., Raj, P. E., Pandithurai, G., Dani, K. K., and Maheskumar, R. S. (2003). Relationship between Lidar-Based Observations of Aerosol Content and Monsoon Precipitation over a Tropical Station, Pune, India. *Meteorol. Appl.* 10, 253–262. doi:10.1017/s1350482703003050

Dutheil, F., Baker, J. S., and Navel, V. (2020). COVID-19 as a Factor Influencing Air Pollution. *Environ. Pollut.* 263 (Pt), 114466. doi:10.1016/j.envpol.2020.114466

Dutta, A., and Jinsart, W. (2021). Air Quality, Atmospheric Variables and Spread of COVID-19 in Delhi (India): An Analysis. *Aerosol Air Qual. Res.* 21, 200417. doi:10.4209/aaqr.2020.07.0417

Farahat, A., Chauhan, A., Al Otaibi, M., and Singh, R. P. (2021). Air Quality Over Major Cities of Saudi Arabia During Hajj Periods of 2019 and 2020. *Earth Systems and Environment* 5 (1), 101–114.

Gautam, S., and Hens, L. (2020). SARS-CoV-2 Pandemic in India: what Might We Expect. *Environ. Dev. Sustain.* 22, 3867–3869. doi:10.1007/s10668-020-00739-5

Gautam, S. (2020). The Influence of COVID-19 on Air Quality in India: A Boon or Inutile. *Bull. Environ. Contam. Toxicol.* 104 (6), 724–726. doi:10.1007/s00128-020-02877-y

Gautam, S., and Trivedi, U. (2020). Global Implications of Bio-Aerosol in Pandemic. *Environ. Dev. Sustain.* 22, 3861–3865. doi:10.1007/s10668-020-00704-2

George, J. P., Harenduprakash, L., and Mohan, M. (2008). Multi Year Changes of Aerosol Optical Depth in the Monsoon Region of the Indian Ocean since 1986 as Seen in the AVHRR and TOMS Data. *Ann. Geophys.* 26, 7–11. doi:10.5194/angeo-26-7-2008

Gherboudj, I., Naseema Beegum, S., and Ghedira, H. (2017). Identifying Natural Dust Source Regions over the Middle-East and North-Africa: Estimation of Dust Emission Potential. *Earth-Science Rev.* 165, 342–355. doi:10.1016/J.EARSCIREV.2016.12.010

Goel, S., Kanazawa, A., and Malik, J. (2020). Shape and Viewpoint Without Keypoints. *European Conference on Computer Vision*. Cham: Springer, 88–104.

Indoitu, R., Kozhoridze, G., Batyrbaeva, M., Vitkovskaya, I., Orlovsky, N., Blumberg, D., et al. (2015). Dust Emission and Environmental Changes in the Dried Bottom of the Aral Sea. *Aeolian Res.* 17, 101–115. doi:10.1016/J.AEOLIA.2015.02.004

Jain, S., and Sharma, T. (2020). Social and Travel Lockdown Impact Considering Coronavirus Disease (Covid-19) on Air Quality in Megacities of india: Present Benefits, Future Challenges and Way Forward. *Aerosol Air Qual. Res.* 20 (6), 1222–1236. doi:10.4209/aaqr.2020.04.0171

Jin, Q., Wei, J., Lau, W. K. M., Pu, B., and Wang, C. (2021). Interactions of Asian mineral Dust with Indian Summer Monsoon: Recent Advances and Challenges. *Earth-Science Rev.* 215, 103562. doi:10.1016/j.earscirev.2021.103562

Kanniah, K. D., Kamarul Zaman, N. A. F., Kaskaoutis, D. G., and Latif, M. T. (2020). COVID-19's Impact on the Atmospheric Environment in the Southeast Asia Region. *Sci. Total Environ.* 736, 139658. doi:10.1016/j.scitotenv.2020.139658

Kaskaoutis, D. G., Kosmopoulos, P. G., Nastos, P. T., Kambezidis, H. D., Sharma, M., and Mehdi, W. (2012). Transport Pathways of Sahara Dust over Athens, Greece as Detected by MODIS and TOMS. *Geomatics, Nat. Hazards Risk* 3 (1), 35–54. doi:10.1080/19475705.2011.574296

Kedia, S., Kumar, R., Islam, S., Sathe, Y., and Kaginalkar, A. (2018). Radiative Impact of a Heavy Dust Storm over India and Surrounding Oceanic Regions. *Atmos. Environ.* 185, 109–120. doi:10.1016/j.atmosenv.2018.05.005

Kerimray, A., Baimatova, N., Ibragimova, O. P., Bukenov, B., Kenessov, B., Plotitsyn, P., et al. (2020). Assessing Air Quality Changes in Large Cities during COVID-19 Lockdowns: The Impacts of Traffic-free Urban Conditions in Almaty, Kazakhstan. *Sci. Total Environ.* 730, 139179. doi:10.1016/j.scitotenv.2020.139179

Khan, A., Khorat, S., Khatun, R., Doan, Q.-V., Nair, U. S. U. S., and Niyogi, D. (2021). Variable Impact of COVID-19 Lockdown on Air Quality across 91 Indian Cities. *Am. Meteorol. Soc.* 25, 57–75. doi:10.1175/EI-D-20-0017.1

Khetan, M. S., Vaishnao, L. S., Kewalramani, M., Kewalramani, M., and Shah, R. J. (2020). Effect of Lockdown Due to COVID-19 Pandemic on Mental Health of Pre-medical Students of Maharashtra. *Int. J. Community Med. Public Health* 7 (9), 3524–3530. doi:10.18203/2394-6040.ijcmph20203917

Klimont, Z., Kupiainen, K., Heyes, C., Purohit, P., Cofala, J., Rafaj, P., et al. (2017). Global Anthropogenic Emissions of Particulate Matter Including Black Carbon. *Atmos. Chem. Phys.* 17, 8681–8723. doi:10.5194/acp-17-8681-2017

Knippertz, P., Deutscher, C., Kandler, K., Müller, T., Schulz, O., and Schütz, L. (2007). Dust Mobilization Due to Density Currents in the Atlas Region: Observations from the Saharan Mineral Dust Experiment 2006 Field Campaign. *J. Geophys. Res.* 112. doi:10.1029/2007jd008774

Kotnala, G., Mandal, T. K., Sharma, S. K., and Kotnala, R. K. (2020). Emergence of Blue Sky over Delhi Due to Coronavirus Disease (COVID-19) Lockdown Implications. *Aerosol Sci. Eng.* 4, 228–238. doi:10.1007/s41810-020-00062-6

Krishnan, R., and Ramanathan, V. (2002). Evidence of Surface Cooling from Absorbing Aerosols. *Geophys. Res. Lett.* 29, 54–61. doi:10.1029/2002GL014687

Kumar, A., Singh, B. P., Punia, M., Singh, D., Kumar, K., and Jain, V. K. (2014a). Assessment of Indoor Air Concentrations of VOCs and Their Associated Health Risks in the Library of Jawaharlal Nehru University, New Delhi. *Environ. Sci. Pollut. Res.* 21 (3), 2240–2248. doi:10.1007/s11356-013-2150-7

Kumar, A., Singh, B. P., Punia, M., Singh, D., Kumar, K., and Jain, V. K. (2014b). Determination of Volatile Organic Compounds and Associated Health Risk Assessment in Residential Homes and Hostels within an Academic institute, New Delhi. *Indoor Air* 24 (5), 474–483. doi:10.1111/ina.12096

Kumar, N., and Tyagi, R. (2021). Various Impacts of COVID-19 on Environmental Pollution. *Int. J. Hum. Capital Urban Manage.* 6 (1), 1–10. doi:10.22034/IJHCUM.2021.01.01

Kumar, P., Hama, S., Omidvarborna, H., Sharma, A., Sahani, J., Abhijith, K. V., et al. (2020). Temporary Reduction in fine Particulate Matter Due to 'anthropogenic Emissions Switch-Off' during COVID-19 Lockdown in Indian Cities. *Sust. Cities Soc.* 62 (May), 102382. doi:10.1016/j.scs.2020.102382

Kumar, S. (2020). Effect of Meteorological Parameters on Spread of COVID-19 in India and Air Quality during Lockdown. *Sci. Total Environ.* 745, 141021. doi:10.1016/j.scitotenv.2020.141021

Kumari, P., and Toshniwal, D. (2020). Impact of Lockdown Measures during COVID-19 on Air Quality- A Case Study of India. *Int. J. Environ. Health Res.* 00 (00), 1–8. doi:10.1080/09603123.2020.1778646

Li, J., Wang, D., Duan, K., and Mubeen, R. (2021). Tourists' Health Risk Threats amid COVID-19 Era: Role of Technology Innovation, Transformation, and Recovery Implications for Sustainable Tourism. *Front. Psychol.* 12, 769175. doi:10.3389/fpsyg.2021.769175

Li, L., Li, Q., Huang, L., Wang, Q., Zhu, A., Xu, J., et al. (2020). Air Quality Changes during the COVID-19 Lockdown over the Yangtze River Delta Region: An Insight into the Impact of Human Activity Pattern Changes on Air Pollution Variation. *Sci. Total Environ.* 732, 139282. doi:10.1016/j.scitotenv.2020.139282

Liu, F., Wang, D., Duan, K., and Mubeen, R. (2021a). 2021-September-03)Social media Efficacy in Crisis Management: Effectiveness of Non-pharmaceutical Interventions to Manage the COVID-19 Challenges [Original Research]. *Front. Psychiatry* 12 (1099), 626134. doi:10.3389/fpsyt.2021.626134

Liu, Q., Qu, X., Wang, D., and Mubeen, R. (2021b). Product Market Competition and Firm Performance: Business Survival through Innovation and Entrepreneurial Orientation amid COVID-19 Financial Crisis. *Front. Psychol.* 12 (4910), 790923. doi:10.3389/fpsyg.2021.79092310.3389/fpsyg.2021.707971

Local Burden of Disease, H. I. V. C. (2021). Mapping Subnational HIV Mortality in Six Latin American Countries with Incomplete Vital Registration Systems. *BMC Med.* 19 (1), 4. doi:10.1186/s12916-020-01876-4

Mahato, S., Pal, S., and Ghosh, K. G. (2002). Effect of Lockdown amid COVID-19 Pandemic on Air Quality of the Megacity Delhi, India. *Sci. Total Environ.* 730, 139086. doi:10.1016/j.scitotenv.2020.139086

Maji, K. J., Namdeo, A., Bell, M., Goodman, P., Nagendra, S. M. S., Barnes, J. H., et al. (2021). Unprecedented Reduction in Air Pollution and Corresponding Short-Term Premature Mortality Associated with COVID-19 Lockdown in Delhi, India. *J. Air Waste Manag. Assoc.* 71, 1085–1101. doi:10.1080/10962247.2021.1905104

Mandal, I., and Pal, S. (2020). COVID-19 Pandemic Persuaded Lockdown Effects on Environment over Stone Quarrying and Crushing Areas. *Sci. Total Environ.* 732, 139281. doi:10.1016/j.scitotenv.2020.139281

Mehmood, K., SaifullahIqbal, M., Iqbal, M., and Abrar, M. M. (2020). Can Exposure to PM2.5 Particles Increase the Incidence of Coronavirus Disease 2019 (COVID-19). *Sci. Total Environ.* 741, 140441. doi:10.1016/j.scitotenv.2020.140441

Meo, S. A., Bukhari, I. A., Akram, J., Meo, A. S., and Klonoff, D. C. (2021). COVID-19 Vaccines: Comparison of Biological, Pharmacological Characteristics and Adverse Effects of Pfizer/BioNTech and Moderna Vaccines. *Eur. Rev. Med. Pharmacol. Sci.*, 1663–1669.

Morsy, M. A., Abdel-Aziz, A. M., Abdel-Hafez, S., Venugopala, K. N., Nair, A. B., and Abdel-Gaber, S. A. (2020). The Possible Contribution of P-Glycoprotein in the Protective Effect of Paeonol Against Methotrexate-Induced Testicular Injury in Rats. *Pharmaceuticals* 13 (9), 223.

Morsy, H., Salami, A., and Mukasa, A. N. (2021). Opportunities Amid COVID-19: Advancing Intra-African Food Integration. *World Development* 139, 105308.

Middleton, N. J. (1986). A Geography of Dust Storms in South-West Asia. *J. Climatol.* 6 (2), 183–196. doi:10.1002/joc.3370060207

Mubeen, R., Han, D., Abbas, J., and Hussain, I. (2020). The Effects of Market Competition, Capital Structure, and CEO Duality on Firm Performance: A Mediation Analysis by Incorporating the GMM Model Technique. *Sustainability* 12 (8), 3480. doi:10.3390/su12083480

Munir, M., Nazeer, W., Rafique, S., and Kang, S. M. (2016). M-Polynomial and Degree-Based Topological Indices of Polyhex Nanotubes. *Symmetry* 8 (12), 149.

Nakajima, T., Yoon, S.-C., Ramanathan, V., Shi, G.-Y., Takemura, T., Higurashi, A., et al. (2007). Overview of the Atmospheric Brown Cloud East Asian Regional Experiment 2005 and a Study of the Aerosol Direct Radiative Forcing in East Asia. *J. Geophys. Res.* 112. doi:10.1029/2007JD009009

Namdari, S., Karimi, N., Sorooshian, A., Mohammadi, G., and Sehatkashani, S. (2018). Impacts of Climate and Synoptic Fluctuations on Dust Storm Activity over the Middle East. *Atmos. Environ.* 173, 265–276. doi:10.1016/J.ATMOSENV.2017.11.016

Navinya, C., Patidar, G., and Phuleria, H. C. (2020). Examining Effects of the COVID-19 National Lockdown on Ambient Air Quality across Urban India. *Aerosol Air Qual. Res.* 20, 1759–1771. doi:10.4209/aaqr.2020.05.0256

NeJhaddadgar, N., Ziapour, A., Zakkipour, G., Abbas, J., Abolfathi, M., and Shabani, M. (2020). Effectiveness of Telephone-Based Screening and Triage during COVID-19 Outbreak in the Promoted Primary Healthcare System: a Case Study in Ardabil Province, Iran. *J. Public Health (Berl.)* 29, 1–6. doi:10.1007/s10389-020-01407-8

Otmani, A., Benchrif, A., Tahri, M., Bounakhla, M., Chakir, E. M., El Bouch, M., et al. (2020). Impact of Covid-19 Lockdown on PM10, SO2 and NO2 Concentrations in Salé City (Morocco). *Sci. Total Environ.* 735 (2), 139541. doi:10.1016/j.scitotenv.2020.139541

Ott, W. R. (1978). Environmental Indices: Theory and Practice.

Pant, G., Alka, D., Garlapati, D., Gaur, A., Hossain, K., Singh, S. V., et al. (2020). Air Quality Assessment Among Populous Sites of Major Metropolitan Cities in India during COVID-19 Pandemic Confinement. *Environ. Sci. Pollut. Res.* 27, 44629–44636. doi:10.1007/s11356-020-11061-y

Paulson, K. R., Kamath, A. M., Alam, T., Bienhoff, K., Abady, G. G., and Kassebaum, N. J. (2021). Global, Regional, and National Progress towards Sustainable Development Goal 3.2 for Neonatal and Child Health: All-Cause and Cause-specific Mortality Findings from the Global Burden of Disease Study 2019. *The Lancet*, 1–36. doi:10.1016/s0140-6736(21)01207-1

Prasad, A. K., Singh, R. P., and Singh, A. (2006). Seasonal Climatology of Aerosol Optical Depth over the Indian Subcontinent: Trend and Departures in Recent Years. *Int. J. Remote Sensing* 27, 2323–2329. doi:10.1080/01431160500043665

Pye, K. (2015). *Aeolian Dust and Dust Deposits*. London, UK: ElsevierAcademic Press, 334.

Rashki, A., Kaskaoutis, D. G., Rautenbach, C. J. d., Eriksson, P. G., Qiang, M., and Gupta, P. (2012). Dust Storms and Their Horizontal Dust Loading in the Sistan Region, Iran. *Aeolian Res.* 5, 51–62. doi:10.1016/J.AEOLIA.2011.12.001

Report, M. W., Yao, Y., Ph, D., Asadi, S., Bouvier, N., Wexler, A. S., et al. (2020). Evaluation of the Potential Relationship between Particulate Matter (PM) Pollution and COVID-19 Infection Spread in Italy. *Atmos. Meas. Tech.* 21 (March), 939–949. doi:10.1080/02786826.2020.1749229

Resmi, C. T., Nishanth, T., Satheesh Kumar, M. K., Manoj, M. G., Balachandramohan, M., and Valsaraj, K. T. (2020). Air Quality Improvement during Triple-Lockdown in the Coastal City of Kannur, Kerala to Combat Covid-19 Transmission. *PeerJ* 8, e9642–20. doi:10.7717/peerj.96422

Ritchie, H., Ortiz-Ospina, E., Hasell, J., Macdonald, B., Giattino, C., and Roser, M. (2020). *Coronavirus Pandemic (COVID-19). Our World in Data – Statistics and Research*. England: Oxford Martin School, The University of Oxford, UK. Global Change Data Lab. Available from: https://ourworldindata.org/coronavirus/ (accessed September 17, 2020).

Selvam, S., Muthukumar, P., Venkatramanan, S., Roy, P. D., Bharath, K. M., and Jesuraja, K. (2020). SARS-CoV-2 Pandemic Lockdown: Effects on Air Quality in the Industrialized Gujarat State of India. *Sci. Total Environ.* 737, 140391.

Sahu, S. K., and Kota, S. H. (2017). Significance of PM2.5 Air Quality at the Indian Capital. *Aerosol Air Qual. Res.* 17, 588–597. doi:10.4209/aaqr.2016.06.0262

Sarkar, S., Chauhan, A., Kumar, R., and Singh, R. P. (2019). Impact of Deadly Dust Storms (May 2018) on Air Quality, Meteorological, and Atmospheric Parameters over the Northern Parts of India. *GeoHealth* 3, 67–80. doi:10.1029/2018GH000170

Sathe, Y., Gupta, P., Bawase, M., Lamsal, L., Patadia, F., and Thipse, S. (2021). Surface and Satellite Observations of Air Pollution in India during COVID-19 Lockdown: Implication to Air Quality. *Sust. Cities Soc.* 66, 102688. doi:10.1016/j.scs.2020.102688

Sharma, S., Zhang, M., Anshika, J., Gao, J., Zhang, H., and Kota, S. H. (2020). Effect of Restricted Emissions during COVID-19 on Air Quality in India. *Sci. Total Environ.* 728, 138878. doi:10.1016/j.scitotenv.2020.138878

Shi, X., and Brasseur, G. P. (2020). The Response in Air Quality to the Reduction of Chinese Economic Activities during the COVID-19 Outbreak. *Geophys. Res. Lett.* 47, 1. doi:10.1029/2020GL088070

Sicard, P., De Marco, A., Agathokleous, E., Feng, Z., Xu, X., Paoletti, E., et al. (2020). Amplified Ozone Pollution in Cities during the COVID-19 Lockdown. *Sci. Total Environ.* 735, 139542. doi:10.1016/j.scitotenv.2020.139542

Singh, B. P., Kumar, A., Singh, D., Punia, M., Kumar, K., and Jain, V. K. (2014). An Assessment of Ozone Levels, UV Radiation and Their Occupational Health hazard Estimation during Photocopying Operation. *J. Hazard. Mater.* 275, 55–62. doi:10.1016/j.jhazmat.2014.04.049

Singh, B. P., Kumar, K., and Jain, V. K. (2021c). Distribution of Ring PAHs in Particulate/gaseous Phase in the Urban City of Delhi, India: Seasonal Variation and Cancer Risk Assessment. *Urban Clim.* 40, 101010. doi:10.1016/j.uclim.2021.101010

Singh, B. P., Kumar, K., and Jain, V. K., (2021a). Source Identification and Health Risk Assessment Associated with Particulate- and Gaseous-phase PAHs at Residential Sites in Delhi, India. *Air Qual. Atmos. Health*, 14, 1505, 1521. doi:10.1007/s11869-021-01035-5

Singh, B. P., and Kumar, P. (2021). Spatio-temporal Variation in fine Particulate Matter and Effect on Air Quality during the COVID-19 in New Delhi, India. *Urban Clim.* 40, 101013. doi:10.1016/j.uclim.2021.101013

Singh, B. P., Singh, K., Kumar, K., and Jain, V. K. (2021b). Study of Seasonal Variation of PM2.5 Concentration Associated with Meteorological Parameters at Residential Sites in Delhi, India. *J. Atmos. Chem.* doi:10.1007/s10874-021-09419

Singh, D., Kumar, A., Kumar, K., Singh, B., Mina, U., Singh, B. B., et al. (2016). Statistical Modeling of O3, NOx, CO, PM2.5, VOCs and Noise Levels in Commercial Complex and Associated Health Risk Assessment in an Academic Institution. *Sci. Total Environ.* 572, 586–594. doi:10.1016/j.scitotenv.2016.08.086

Srivastava, S., Kumar, A., Bauddh, K., Gautam, A. S., and Kumar, S. (2020). 21-Day Lockdown in India Dramatically Reduced Air Pollution Indices in Lucknow and New Delhi, India. *Bull. Environ. Contam. Toxicol.* 105, 9–17. doi:10.1007/s00128-020-02895-w

Su, Z., McDonnell, D., Cheshmehzangi, A., Abbas, J., Li, X., and Cai, Y. (2021a). The Promise and Perils of Unit 731 Data to advance COVID-19 Research. *BMJ Glob. Health* 6 (5), e004772. doi:10.1136/bmjgh-2020-004772

Su, Z., McDonnell, D., Wen, J., Kozak, M., Abbas, J., Šegalo, S., et al. (2021b). Mental Health Consequences of COVID-19 media Coverage: the Need for Effective Crisis Communication Practices. *Glob. Health* 17 (1), 4. doi:10.1186/s12992-020-00654-4

Su, Z., WenMcDonnell, J., Abbas, J., McDonnell, D., Cheshmehzangi, A., Li, X., et al. (2020). A Race for a Better Understanding of COVID-19 Vaccine Non-adopters. *Brain Behav. Immun. - Health* 9, 100159. doi:10.1016/j.bbih.2020.100159

Suhaimi, N. F., Jalaludin, J., and Latif, M. T. (2020). Demystifying a Possible Relationship between COVID-19, Air Quality and Meteorological Factors: Evidence from Kuala Lumpur, Malaysia. *Aerosol Air Qual. Res.* 20, 1520–1529. doi:10.4209/aaqr.2020.05.0218

Tobías, A., Carnerero, C., Reche, C., Massagué, J., Via, M., Minguillón, M. C., et al. (2020). Changes in Air Quality during the Lockdown in Barcelona (Spain) One Month into the SARS-CoV-2 Epidemic. *Sci. Total Environ.* 726, 138540. doi:10.1016/j.scitotenv.2020.138540

Torkmahalleh, M. A., Hopke, P. K., Broomandi, P., Naseri, M., Abdrakhmanov, T., Ishanov, A., et al. (2020). Exposure to Particulate Matter and Gaseous Pollutants During Cab Commuting in Nur-Sultan City of Kazakhstan. *Atmospheric Pollution Research* 11 (5), 880–885.

Türkeş, M. (2017). "Recent Spatiotemporal Variations of Synoptic Meteorological Sand and Dust Storm Events Observed over the Middle East and Surrounding Regions," in Proceedings of the 5th International Workshop on Sand and Dust Storms (SDS): Dust Sources and their Impacts in the Middle East, 23–25 October 2017 (Turkey: Istanbul), 45–59.

Vadrevu, K. P., Eaturu, A., Biswas, S., Lasko, K., Sahu, S., Garg, J. K., et al. (2020). Spatial and Temporal Variations of Air Pollution over 41 Cities of India during the COVID-19 Lockdown Period. *Sci. Rep.* 10, 1–15. doi:10.1038/s41598-020-72271-5

Verma, R. L., and Kamyotra, J. S. (2021). Impacts of COVID-19 on Air Quality in India. *Aerosol and Air Quality Research*, 21.

Wang, C., Wang, D., Abbas, J., Duan, K., and Mubeen, R. (2021). Global Financial Crisis, Smart Lockdown Strategies, and the COVID-19 Spillover Impacts: A Global Perspective Implications from Southeast Asia. *Front. Psychiatry* 12 (1099), 643783. doi:10.3389/fpsyt.2021.643783

Wang, J. X. L. (2015). Mapping the Global Dust Storm Records: Review of Dust Data Sources in Supporting Modeling/Climate Study. *Curr. Pollut. Rep* 1, 82–94. doi:10.1007/s40726-015-0008-y

Wang, P., Chen, K., Zhu, S., Wang, P., and Zhang, H. (2020a). Severe Air Pollution Events Not Avoided by Reduced Anthropogenic Activities during COVID-19 Outbreak. *Resour. Conservation Recycling* 158 (February), 104814. doi:10.1016/j.resconrec.2020.104814

Wang, P., Qiao, X., and Zhang, H. (2020b). Modeling PM2.5 and O3 with Aerosol Feedbacks Using WRF/Chem over the Sichuan Basin, Southwestern China. *Chemosphere* 254, 126735. doi:10.1016/j.chemosphere.12673510.1016/j.chemosphere.2020.126735

Wang, Y., Yuan, Y., Wang, Q., Liu, C., Zhi, Q., and Cao, J. (2020). Changes in Air Quality Related to the Control of Coronavirus in China: Implications for Traffic and Industrial Emissions. *Sci. Total Environ.* 731 (December 2019), 139133. doi:10.1016/j.scitotenv.2020.139133

World Health Organisation (2020). World Health Organization Coronavirus Disease (COVID-19) Pandemic, WHO. Accessed from https://www.who.int/emergencies/diseases/novel-coronavirus-2019 on 31 March 2020.

World Health Organisation (2020). *World Health Organization, Coronavirus Disease*. (COVID-2019) India Situation Report – 1 https://www.who.int/docs/default-source/wrindia/india-situation-report-1.pdf?sfvrsn=5ca2a672_0 (Accessed January 31, 2020).

World metros (2021). (Accessed October 4, 2021)https://www.worldometers.info/coronavirus/.

Wu, F., Zhao, S., Yu, B., Chen, Y.-M., Wang, W., Song, Z.-G., et al. (2020). A New Coronavirus Associated with Human Respiratory Disease in China. *Nature* 579 (7798), 265–269. doi:10.1038/s41586-020-2008-3

Xi, X., and Sokolik, I. N. (2015). Seasonal Dynamics of Threshold Friction Velocity and Dust Emission in Central Asia. *J. Geophys. Res. Atmos.* 120, 1536–1564. doi:10.1002/2014JD022471

Xie, J., and Zhu, Y. (2020). Association between Ambient Temperature and COVID-19 Infection in 122 Cities from China. *Sci. Total Environ.* 724, 138201. doi:10.1016/j.scitotenv.2020.138201

Lebni, J., Abbas, J., Khorami, F., Khosravi, B., Jalali, A., and Ziapour, A. (2020). Challenges Facing Women Survivors of Self-Immolation in the Kurdish Regions of Iran: A Qualitative Study. *Front. Psychiatry* 11, 778. doi:10.3389/fpsyt.2020.00778

Yu, K., D'Odorico, P., Bhattachan, A., Okin, G. S., and Evan, A. T. (2015). Dust-rainfall Feedback in West African Sahel. *Geophys. Res. Lett.* 42, 7563–7571. doi:10.1002/2015GL065533

Zambrano-Monserrate, M. A., Ruano, M. A., and Sanchez-Alcalde, L. (2020). Indirect Effects of COVID-19 on the Environment. *Sci. Total Environ.* 728, 138813. doi:10.1016/j.scitotenv.2020.138813

Zheng, J. (2020). SARS-CoV-2: an Emerging Coronavirus that Causes a Global Threat. *Int. J. Biol. Sci.* 16 (10), 1678–1685. doi:10.7150/ijbs.45053

Zhu, Y., Xie, J., Huang, F., and Cao, L. (2020). Association between Short-Term Exposure to Air Pollution and COVID-19 Infection: Evidence from China. *Sci. Total Environ.* 727, 138704. doi:10.1016/j.scitotenv.2020.138704

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's Note: All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.