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The Impact of COVID-19 Lockdowns on Air Quality —A Global Review

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Abstract: The outbreak of the COVID-19 pandemic has emerged as a serious public health threat and has had a tremendous impact on all spheres of the environment. The air quality across the world improved because of COVID-19 lockdowns. Since the outbreak of COVID-19, large numbers of studies have been carried out on the impact of lockdowns on air quality around the world, but no studies have been carried out on the systematic review on the impact of lockdowns on air quality. This study aims to systematically assess the bibliographic review on the impact of lockdowns on air quality around the globe. A total of 237 studies were identified after rigorous review, and 144 studies met the criteria for the review. The literature was surveyed from Scopus, Google Scholar, PubMed, Web of Science, and the Google search engine. The results reveal that (i) most of the studies were carried out on Asia (about 65%), followed by Europe (18%), North America (6%), South America (5%), and Africa (3%); (ii) in the case of countries, the highest number of studies was performed on India (29%), followed by China (23%), the U.S. (5%), the U.K. (4%), and Italy; (iii) more than 60% of the studies included NO_2 for study, followed by $PM_{2.5}$ (about 50%), PM_{10}, SO_2, and CO; (iv) most of the studies were published by *Science of the Total Environment* (29%), followed by *Aerosol and Air Quality Research* (23%), *Air Quality, Atmosphere & Health* (9%), and *Environmental Pollution* (5%); (v) the studies reveal that there were significant improvements in air quality during lockdowns in comparison with previous time periods. Thus, this diversified study conducted on the impact of lockdowns on air quality will surely assist in identifying any gaps, as it outlines the insights of the current scientific research.

Keywords: COVID-19; air quality; lockdown; public health; *Science of the Total Environment*; scientific research

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1. Introduction

The novel coronavirus (SARS-CoV-2) originated from Wuhan in December 2019, and later spread to many countries across the world [1]. The World Health Organization (WHO) declared this virus a "global pandemic" on 11 March 2020. In many parts of the world, severely affected countries imposed lockdowns to prevent the transmission of COVID-19 by restricting transportation, economic, and industrial activities. Thus, restrictions on human activities and the various productive activities of industries and farms resulted in unforeseen impacts and improved the health of the environment to a great extent. The air quality also significantly improved across the globe because of the restricted emissions from different sources during lockdowns. In many previous research studies, it is well-documented that many countries of the world are facing serious public health problems due to extreme air pollution [2–5]. More than 60% of the populations living in urban areas are severely exposed to the serious problem of air pollution [1]. Both high-income (56%) and low-income (98%) countries of the world fail to meet the guidelines proposed by WHO [1]. As per the reports published by WHO [1], more than 4.2

billion people have lost their lives because of health risks related to air pollution [1]. Air pollution has become one of the most significant health risks [6–9] and results in great loss of life. According to an estimation by the Global Burden of Disease Project of the WHO, 1.1 million premature deaths were reported in 2016 primarily because of outdoor particulate matter ($PM_{2.5}$) pollution [10]. The WHO [1] recently released a report from the Global Ambient Air Quality Database on the concentration of $PM_{2.5}$ across 100 countries of the world and it was observed that the concentration of $PM_{2.5}$ was relatively higher across the cities of developing countries, such as India, Bangladesh, Pakistan, the Middle East, Afghanistan, and Mongolia. Developing cities, such as Delhi (India), Dhaka (Bangladesh), Kabul (Afghanistan), Manama (Bahrain), and Beijing (China) are vulnerable to extreme air pollution.

The recent outbreak of COVID-19 has had an immense impact on air quality across the world [11–15]. After the outbreak of COVID-19, a large number of studies were performed on the impact of lockdowns on air quality [16–18]. The concentration of major air pollutants, such as $PM_{2.5}$, PM_{10}, SO_2, CO, and NO_2, were reduced by about 30% because of lockdowns [19]. Similar studies were conducted in Spain [20], Italy [21], Brazil [22], (Morocco [23], India [24], the U.S. [25], and Bangladesh [26]. All the studies concluded that there was a significant reduction in air pollutants, and a significant improvement in air quality during lockdown due to COVID-19.

According to Muhammad et al. [27], there were substantial decreases in fuel demand around the world during lockdown periods due to the cessation of transportation and industrial activities. The reduced demand for fuel resulted in the drastic reduction of carbon emissions and air pollutant concentrations [15–17,28,29]. To the best of our knowledge, there have been no review studies performed on the impact of lockdowns on air quality across the globe until now. Considering this research gap, this study aims to assess a review on the impact of lockdown on air quality across the world. This study includes more than 40 countries across the world from six continents, and more than 140 research studies. This is the first attempt at dealing with the assessment of a systematic review on the impact of COVID-19 lockdowns on air quality on a global scale. The findings of this study could help planners and policymakers understand, as well as implement, effective strategies for the reduction of air pollution levels at the city, regional, and country scales.

2. Materials and Methods

At the beginning of the study, a total of 237 research studies were searched using keywords. From the 237 research studies, 144 research papers were finally selected on the basis of two criteria. In the initial stages, the studies were shortlisted through the screening of the abstracts and titles of the papers. At the second stage of the literature screening, the articles were selected on the basis of the scales of the studies (the city, regional, and country scales). Thus, 144 articles were finally included in this literature screening. Before the final selection of studies for this review assessment, some criteria were set. First, the studies performed on the impact of lockdowns on the air quality at the city, regional, and country scales were included in this review process. Secondly, the literature screening was carried out from March 2020 to April 2021, and no studies published after April 2021 were considered. Thirdly, the studies performed on multiple countries, or cities from multiple countries, were not considered for the review process. The details of the literature screening procedures are presented in Figure 1. Previous literature was considered on the basis of the objectives of the study (Tables 1 and 2), i.e., studies performed on the impact of lockdowns on the air quality at the city, regional and country scales, respectively. The entire process of the literature screening is shown through a PRISMA flow diagram [30] (Figure 2).

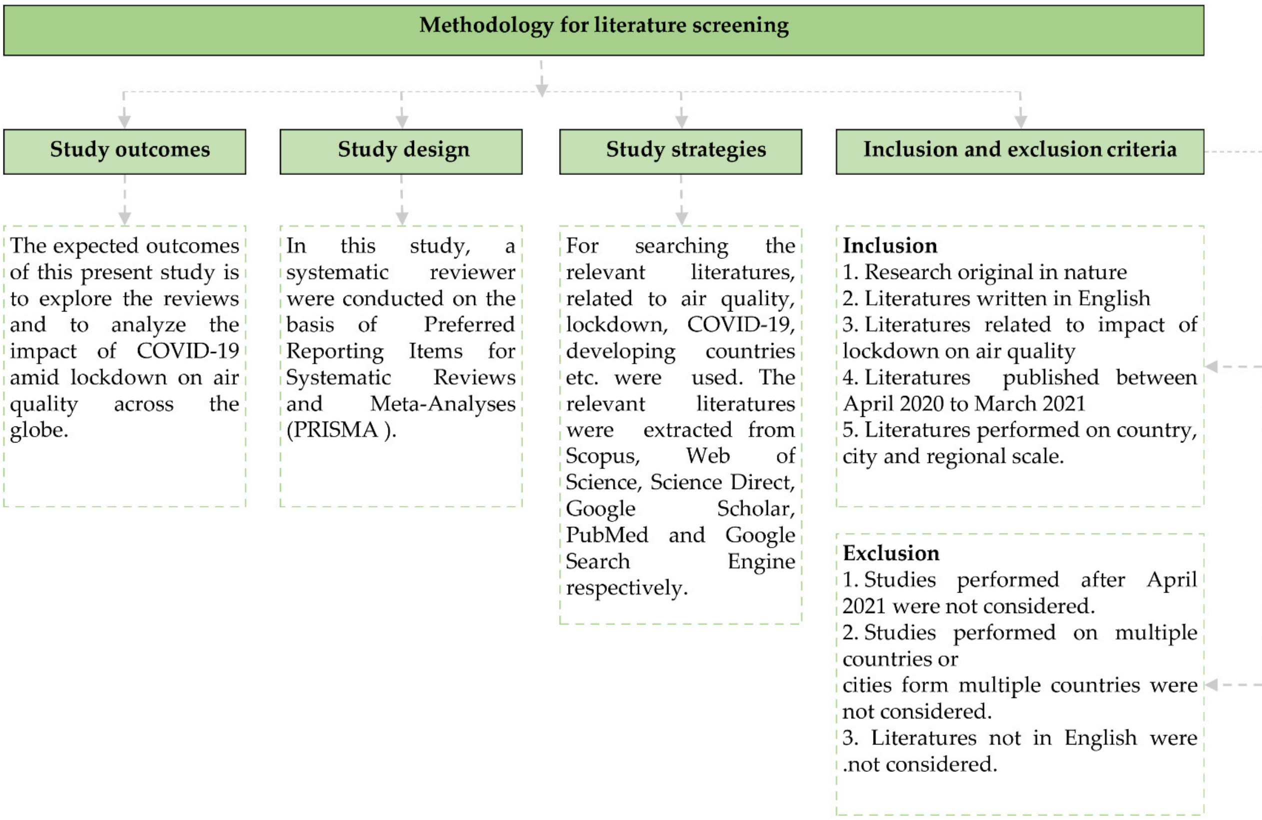

Figure 1. Details of the methodology used in this literature review.

Table 1. Distribution of literature across major continents (until April 2021).

Continents	Country	Number of Studies
Europe (33)	UK (8), Turkey (3), France (2), Spain (6), Italy (7), Germany (1), Poland (1), Netherland (1), Portugal (1), Russia (1), Macedonia (1), Albania (1),	33
North and South America (20)	USA (9), Canada (1), Ecuador (4), Brazil (4), Mexico (2),	20
Asia (117)	India (53), China (42), Thailand (2), Bangladesh (5), Malaysia (2), Singapore (1), Iran (1), Israel (1), Japan (1), Pakistan (3), Vietnam (1), Korea (3), Kazakhstan (1), Saudi Arabia (1)	117
Oceania (2)	Australia (2)	2
Africa (7)	Nigeria (1), Morocco (3), Egypt (2), Uganda (1)	7

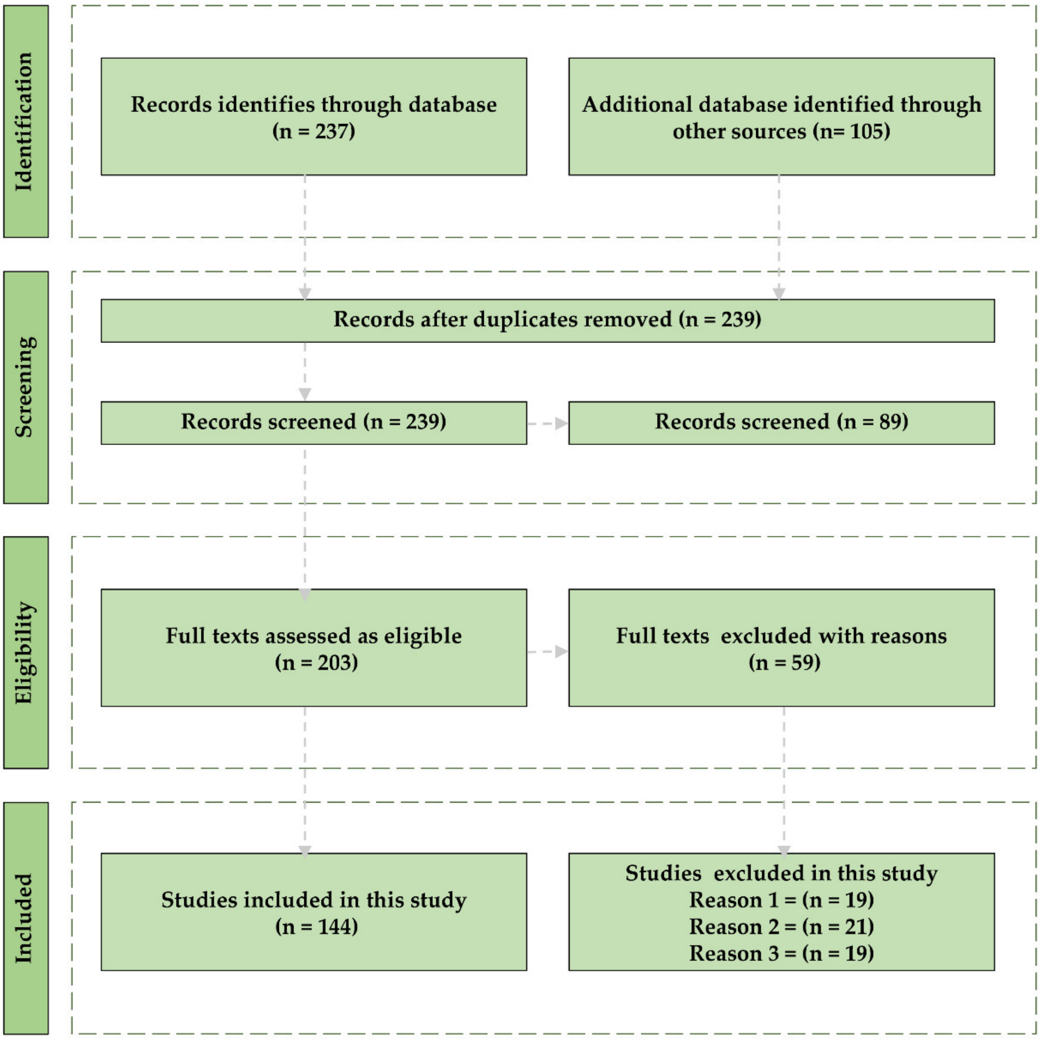

Figure 2. PRISMA flow diagram showing procedure used for systematic review.

Table 2. Country-wide distribution of the literature across the world.

Continent	Country	Number of Studies	% of Studies
Asia	India	53	29.44
	China	42	23.33
	Bangladesh	5	2.78
	Thailand	2	1.11
	Pakistan	3	1.67
	Malaysia	2	1.11
	Korea	3	1.67
	Israel	1	0.56
	Iran	1	0.56
	Vietnam	1	0.56
	Kazakhstan	1	0.56
	Saudi Arabia	1	0.56
	Teheran	1	0.56
	Singapore	1	0.56
Europe	UK	8	4.44
	Spain	6	3.33
	Italy	7	3.89

	Turkey	3	1.67
	Russia	1	0.56
	Germany	1	0.56
	Macedonia	1	0.56
	Albania	1	0.56
	Portugal	1	0.56
	Netherlands	1	0.56
	Poland	1	0.56
	Serbia	1	0.56
	France	2	1.11
North America	US	9	5.00
	Canada	1	0.56
Africa	Morocco	3	1.67
	Egypt	2	1.11
	Kampala	1	0.56
	Nigeria	1	0.56
South America	Brazil	4	2.22
	Ecuador	4	2.22
	Mexico	2	1.11
Oceania	Australia	1	0.56

Keywords for Search of Academic Databases

The main objective of this study was to examine the impact of COVID-19 lockdowns on air quality. Thus, keywords, such as "air pollution", "air quality", "lockdown", "COVID-19", and "pandemic" were used. The main databases searched were Scopus, Web of Science, Science Direct, Google Scholar, PubMed, and the Google search engine. The majority of the articles were searched from Google Scholar, followed by Scopus, Web of Science, and the Google search Engine, from March 2020 to April 2021 (Figure 1).

3. Results

3.1. Geographical Distribution and COVID-19 Studies

In the present analysis, about 70% of the total papers were published in 2020 (particularly from March to December) and the rest of the papers were published (30%) in 2021 (considered up to the month of April). This study encompasses five continents: Asia, Europe, Africa, North America, and South America. About 65% of the total studies were surveyed from Asia, followed by Europe (18%), Africa (7%), North America (6%), South America (6%), and Australia (1%). In the case of countries, the highest number of studies were surveyed from India (29%), followed by China (23%), the U.S. (6%), the U.K. (5%), Italy (3.8%), and Bangladesh (2.78%) (Figure 3).

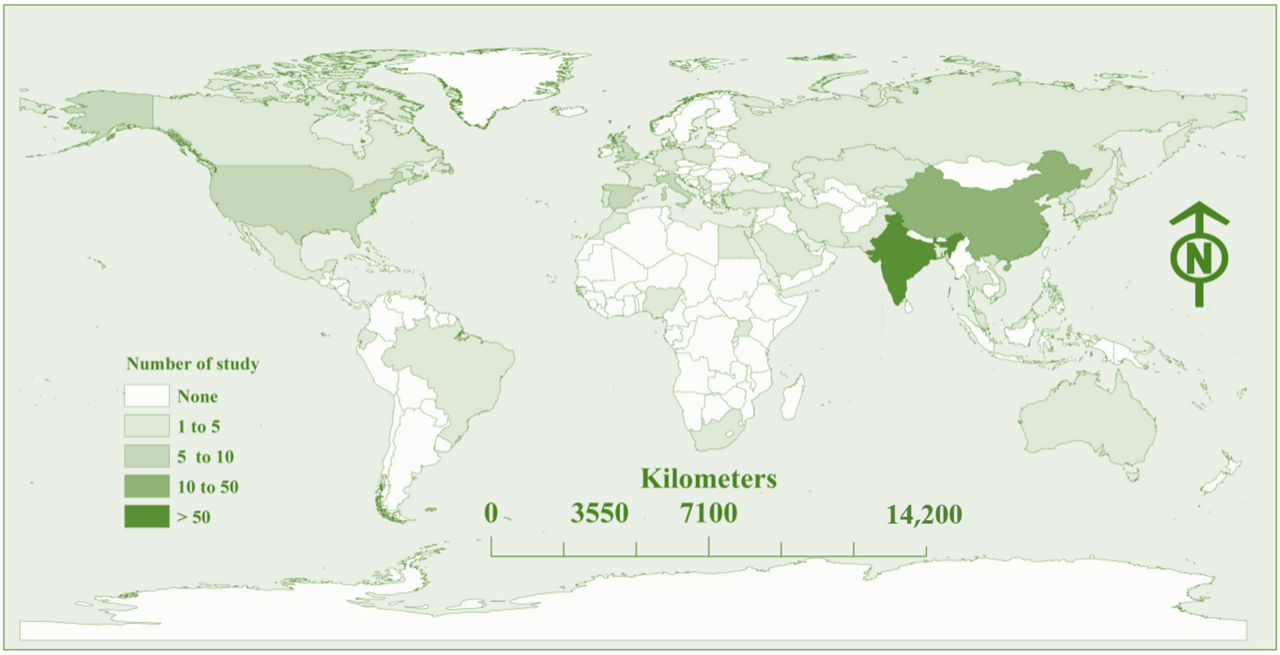

Figure 3. Global scenario of air quality studies (from March 2020 to April 2021).

3.2. Impact of COVID-19 on Air Quality over Asian Countries

From the overall studies surveyed, it was observed that the greatest number of studies on the impact of the COVID-19 pandemic on air quality was performed on Asian countries (65%). As per our literature survey, it is documented that about 45% of the research studies on the impact of COVID-19 on air quality was identified from India, followed by China (36%), Bangladesh (4%), Pakistan (2.6), Korea (2.6%), and Thailand (1.7%). In India, most of the studies were performed on polluted cities and large megacities, such as Delhi, Mumbai, Kolkata, Chennai, Bengaluru, Varanasi, Patna, Gaya, Hyderabad, and Pune. About 60% of the studies were performed over the megacity, Delhi (the capital city of India). In China, most of the studies were performed on large cities, such as Wuhan, Beijing, the megacity Hangzhou, Anqing, Hefei, and the city of Suzhou (Table 3). The studies focusing on the concentrations of $PM_{2.5}$ are shown in Figure 4.

Table 3. Literature on the impact of COVID-19 on air quality in Asian countries.

Country	Study Area	Publication Year	Major Findings
India	City scale	2020	A substantial decrease in $PM_{2.5}$ and the air quality index (AQI) was reported for Delhi, Mumbai, Hyderabad, Kolkata, and Chennai. (ii) $PM_{2.5}$ concentrations were reduced by 34.52% and 27.57% in Kolkata and Delhi, respectively, in comparison to 2019 [18].
	Country	2020	There was a remarkable decline in the ambient air quality index (AQI) (17.75% and 20.70%, respectively) during post-lockdown periods as compared to pre-lockdown periods (ii) poor air quality had a positive correlation with COVID-19 mortalities (r = 0.435 for AQI) [31].
	State	2020	There was a substantial reduction in air pollutants during different phases of lockdowns (ii) $PM_{2.5}$ and PM_{10} decreased by about 17.76% and 20.66%, respectively, during consecutive periods of lockdowns [32].
	City scale	2021	$PM_{2.5}$ was reduced by about 40 to 45% during lockdown periods in comparison to the previous two years [33].

	City scale	2020	Particulate matter concentration decreased by about 40% during lockdown in comparison to previous years [34].
	City scale	2020	The lockdown measures reflected a significant reduction in air pollutants; the most significant fall was estimated for NO_2 (29.3–74.4%), while the least reduction was noticed for SO_2 [35].
	City scale	2020	The average value of AQI at Punjab Bagh was noticed as 212 before the lockdown, which dropped down to 74 during the lockdown, indicating a significant improvement in air quality [23].
	City scale	2020	The results indicate the lowering of $PM_{2.5}$, PM_{10}, and NO_2 concentrations in the city by 93%, 83%, and 70%, respectively, from 25 February 2020 to 21 April 2020 [17].
	City scale	2020	The concentration of NO_2 and $PM_{2.5}$ significantly decreased due to lockdowns across cities [36].
	City scale	2020	These two cities observed a substantial decrease in nitrogen dioxide (40–50%) compared to the same period last year [37].
	City scale	2020	Major negative effects on the social and surrounding environment have been reported due to COVID-19, however positive effects have also been observed with respect to air quality. The results have been taken from the National Aeronautics and Space Administration (NASA), and indicate a significant reduction (50%) in the air quality of the Indian region [23].
	City Scale	2020	A considerable reduction (~30–70%) in NO_2 was found, except for a few sites in the central region. A similar pattern was observed for CO having a ~20–40% reduction. The reduction observed for $PM_{2.5}$, PM_{10}, NO_2, and the enhancement in O_3 was proportional to the population density [38].
	City scale	2021	$PM_{2.5}$ has declined by 14%, by about 30% for NO_2 in million-plus cities, and a 2.06% CO, SO_2 within the range of 5 to 60%, whereas the concentration of O_3 has increased by 1 to 3% in the majority of cities compared with pre-lockdown. On the other hand, CPCB/SPCB data showed a more than 40% decrease in $PM_{2.5}$ and a 47% decrease in PM10 in north Indian cities, more than a 35% decrease in NO2 in metropolitan cities, more than an 85% decrease in SO_2 in Chennai and Nagpur, and a more than 17% increase in O_3 in five cities during 43 days of pandemic lockdown [39].
	City scale	2020	The lockdown effect due to COVID-19 in the city: the complete closure of industries, transports, markets, shopping malls, recreation units, construction works, etc., which are the main sources of CO_2 emissions [40].
	City scale	2021	Highest levels of PM_{10} and $PM_{2.5}$ were observed near sunrise, with little change in the time of maximum levels between 2019 and 2020 [41].
	City scale	2020	A reduction of almost 60% in the particulate matter pollution, and up to 40% in the NOx pollution, were observed, while the ozone levels were reduced by 30–40%, as compared to the same period during the previous two years [42].
	City scale	2021	The air quality has improved across the country and the average temperature and maximum temperature were connected to the outbreak of the COVID-19 pandemic [43].
	City scale	2020	Before 30 days of lockdown, $PM_{2.5}$ was 65.77 $\mu g/m^3$ and that reached 42.72 $\mu g/m^3$ during lockdown periods [44].

	City scale	2021 (a)	During lockdown, maximum decrease was reported for NO_2 (40%), followed by $PM_{2.5}$ (32%), PM_{10} (24%), and SO_2 (18%) [45].
	City scale	2021 (b)	During entire periods of lockdown, the average concentration of PM2.5 declined by 50% [46].
	City scale	2020	Suspended particulate matter (SPM) was reduced by about 36%. The concentration of NO_2 was also reduced during lockdown periods [46].
	City	2020	The concentration of $PM_{2.5}$, PM_{10}, and NO_2 declined by about 50%, with a significant increase in O3 in Delhi ($p < 0.05$) [35].
	Country	2021	Over the urban agglomerations (UAs), and rural regions, the concentrations of NO2 were reduced by about 20–40% and 15–25%, respectively [47].
	Regional	2020	Mumbai recorded the highest decrease of NO_2 (34%) with a seasonal decrease of SO_2 in western and southern India [48].
	City	2021	During lockdown periods, the concentration of $PM_{2.5}$ and PM_{10} declined by about 43% and 59%, respectively, in Delhi, and by 50% and 49%, respectively, in Kolkata [49].
	City	2020	During the initial periods of lockdown, the concentration of $PM_{2.5}$ declined by about 40 to 70% (from 25 March to 31 March 2020) [50].
	City	2020	From 11 May to 9 June 2020, the concentrations of $PM_{2.5}$, PM_{10}, and NO_2 were reduced by about 74%, 46%, and 63%, respectively [51].
	City	2020	There was a substantial decrease in $PM_{2.5}$, PM_{10}, and NO_2 during lockdown, with the highest decline in Ahmedabad (68%), Delhi (71%), Bangalore (87%), and Nagpur (63%), for $PM_{2.5}$, PM_{10}, NO_2 and CO, respectively [16].
	City	2020	NO_2 was reduced by about 46% and the air quality index (AQI) improved by about 27% [52].
	City	2020	Air quality index (AQI) was reduced by 44, 33, 29, 15, and 32% in north, south, east, central and western India. The highest decrease was reported for $PM_{2.5}$ (43%), followed PM_{10} (33%), NO_2 (18%), and CO (10%) [53].
	City	2020	Air pollutants ($PM_{2.5}$, PM_{10}, NO_2, and CO) were reduced by about 50% across the megacities of India [54].
	City	2020	The concentration of $PM_{2.5}$ was reduced by about 19 to 43% in Chennai, 41 to 53% in Delhi, 26 to 54% in Hyderabad, 24 to 36% in Kolkata, and 10 to 39% in Mumbai [55].
	City	2020	The concentrations of $PM_{2.5}$, PM_{10}, NO_2 and SO_2 were 49, 55, 60 and 19%, respectively, in Delhi, and 44, 37, 78, and 39%, respectively, in Mumbai [56].
	City	2020	PM_{10} was reduced by more than 46% across five cities [57].
	City	2020	Over the urban agglomerations (UAs) and rural regions, the concentrations of NO_2 were reduced by about 20–40%, and 15–25%, respectively [58].
	City	2021	The concentrations of PM_{10}, $PM_{2.5}$, NO_x, SO_2, and CO were reduced by about 58, 47, 83, 11, and 30%, respectively [59].
	City	2020	The concentration of $PM_{2.5}$ decreased from 72.9 μg m^{-3} (2019) to 45.9 μg m^{-3} (2020) during lockdown periods [60].
	City scale	2020	The concentrations of $PM_{2.5}$, PM_{10}, SO_2, CO_2, and NO_2 decreased due to lockdown [17].

	Country and City scale	2020	Air quality improved by about 25% during lockdown periods [61].
	City scale	2020	The over-standard multiples method and a grey relational analysis to study the individual and overall change trends of pollutants in Wuhan during the same period in the past seven years. The results show that the concentrations of SO_2 and O_3 increased because of the pandemic, but still met the standard [62].
	City Scale	2020	Urban aerosols decreased from 27.1% for pre-C19Q aerosols to only 17.5% during C19Q. WRF-Chem reported a ~0.2 °C warming across east-central China that represented a minor, though statistically significant, contribution to C19Q temperature anomalies. The largest area of warming is concentrated south of Chengdu and Wuhan, where temperatures increased between +0.2–0.3 °C [63].
	City scale	2021	The increment in secondary organic and inorganic aerosols under stationary weather reached up to 36.4% and 10.2%, respectively, which was further intensified by regional transport. PRD was quite the opposite. The emission reductions benefited PRD air quality, while regional transport corresponded to an increase of 17.3% and 9.3% in secondary organic and inorganic aerosols, respectively. In different regions, the maximum daily 8 h average ozone (O3) soared by 20.6–76.8% in YRD but decreased by 15.5–28.1% in PRD. In YRD, nitrogen oxide (NOx) reductions enhanced O_3 accumulation and, hence, increased secondary aerosol formation [64].
	City scale	2020	It was found that the COVID-19 pandemic caused $PM_{2.5}$ and AQI to decrease by about 7 μg/m^3 and 5-points, respectively [65].
	City scale	2021	The precipitous decrease of AQI and PCDI in Q1 2020, and the peaks of the AQI during the epidemic period were closely related to people's activities. AQI, $PM_{2.5}$, and NO_2 were significantly positively correlated with PCDI [66].
	City scale	2020	The average concentrations of $PM_{2.5}$, PM_{10}, SO_2, CO, and NO_2 were 89.4 μg m–3, 106 μg m^{-3}, 2.31 ppb, 0.72 ppm, and 12.3 ppb, respectively, and were 17.9%, 30.8%, 83.8%, 19.8%, and 62.1%, lower than those in February from 2017–2019. However, the average O_3 concentration was 31.8 ppb in February 2020 [67].
	City scale	2021	$PM_{2.5}$, PM_{10}, SO_2, and NO_2 during a 2-week portion of the lockdown period (from 24 January–6 February) were reduced by −19.2%, −44.7%, −21.5%, and −33.6%, respectively, compared to the same period in 2019. Even with the decrease in $PM_{2.5}$ and PM_{10} concentrations, they were still more than four times higher than the World Health Organization standards (10μg/m^3 and 20 μg/m^3, respectively) [68].
	City scale	2020	Average concentrations of $PM_{2.5}$ and PM_{10} across China were 10.5% and 21.4% lower, respectively, during the lockdown period. The largest reductions were in Hubei province, where NO_2 concentrations were 50.5% lower than expected during the lockdown [69].
	City scale	2020	$PM_{2.5}$ and PM_{10} were reduced by about 10%, 12% [70].
	City scale	2020	The AQIs in these cities were brought down by 6.34 points ($PM_{2.5}$ was down by 7.05 μg m^{-3}) relative to the previous year. The lockdown effects were greater in colder, richer, and more industrialized cities [61].

	City scale	2020	In January (2020), average concentration of PM2.5 and PM10 was 23.8% and 33.9% (over Anqing, Hefei and Suzhou) which was lower in comparison to previous year (2017-2019) [15].
	City scale	2020	The pandemic promoted a decrease in $PM_{2.5}$, PM_{10}, and NO_2 concentrations, but it had just reached the standard or even exceeded the standard [71].
China	City scale	2020	The concentrations of SO_2 and O_3 increased but still met the standard. However, the pandemic promoted a decrease in $PM_{2.5}$, PM_{10}, and NO_2 concentrations, but it had just reached the standard or even exceeded the standard [62].
	Country and City scale	2020	O_3 responses to NO_2 declines can be affected by the primary dependence on its precursors [72].
	City scale	2021	The air quality index (AQI) during the lockdown period decreased by 7.4%, and by 23.48%, compared to pre-lockdown levels and the identical lunar period during the past 3 years, respectively, which exhibited optimal air quality due to reduced emissions [73].
	City scale	2020	A causal relationship between P and R across 31 provincial capital cities in China was established via matching. A higher P resulted in a higher R in China. A 10 μg/m^3 increase in P produced a 0.9% increase in R ($p < 0.05$). An interaction analysis between P and absolute humidity (AH) showed a statistically significant positive relationship between P × AH and R ($p < 0.01$). When AH was ≤ 8.6 g/m^3, higher P and AH produced a higher R ($p < 0.01$) [74].
	City scale	2021	The number of days with NO_2, PM_{10}, and $PM_{2.5}$ as the primary pollutants decreased by approximately 10, 9, and 15%, respectively. We compared the wind direction, wind speed, temperature, and relative humidity from January-April 2020, 2019, 2018, and 2017, and found no obvious correlation between meteorological factors and improved air quality during the 2020 lockdown [75].
	Country	2020	The concentrations of CO and NO_2 were reduced by about 20% and 30%, respectively [76].
	City	2021	During lockdown periods, $PM_{2.5}$ decreased by about 30% and NO_2 by 50%, respectively [77].
	City	2020	The concentration of $PM_{2.5}$, PM_{10}, NO_2, and SO_2 decreased by about 6, 14, 25, and 7%, respectively [78].
	City	2021	The $PM_{2.5}$ and SO_2 were reduced from 37 to 26 ug/m^3 and from 6 to 4 ug/m^3, respectively, during restricted lockdown periods [79].
	City	2020	The concentration of $PM_{2.5}$ was higher during New Year holidays in 2020 (73%) than New Year holidays in 2019 (59%) [80].
	Country	2020	In comparison to last year (2019), the concentrations of CO, NO_2, SO_2, $PM_{2.5}$, and PM_{10} were reduced by about 12, 16, 12, 15, and 14%, respectively [81].
	Country	2021	Lockdown resulted in about a 50% reduction in NO_2 [82].
	Country	2021	The NO_2 was reduced by about 53, 50, and 30% in Wuhan, Hubei province, and China, respectively. The concentration of $PM_{2.5}$ declined by about 35, 29, and 19%, respectively, in comparison to last year [83].
	Country	2020	NO_2 declined by about 24% during the Chinese New Year (CNY) holiday [84].

	Country	2020	The concentration of NO2 was reduced by about 20 to 50% for cities, 15 to 40% for maritime transport, and 40% for power plants [85].
	Regional	2020	There were reductions of $PM_{2.5}$ concentration from 22.9% to 43% during lockdown periods, as compared to previous year [86].
	City	2020	A substantial reduction of $PM_{2.5}$, PM_{10}, CO, and SO_2 were reported during lockdown periods [87].
	Country	2020	Air pollution was reduced by up to 90% during city lockdown [88].
	Regional	2020	The concentrations of $PM_{2.5}$, PM_{10}, and CO decreased by about 40%, 45%, and 24%, respectively, during lockdown periods [89].
	Regional	2020	Lockdown resulted in a substantial reduction in $PM_{2.5}$ (27–46%), NO_2 (29–47%), and SO2 (16–26%) [90].
	Regional	2020	Carbonaceous particles decreased by about 20% during lockdown periods [91].
	City	2020	During lockdown periods, the concentration of PM2.5 and NO_2 decreased by about 36% and 53%, respectively, and O_3 increased by about 116% [92].
	Country	2020	During lockdown periods, the concentration of $PM_{2.5}$ decreased by up to 23 ug/m^3 [93].
Thailand	City scale	2020	Air quality improved by about 50% to 70% during lockdown periods due to restricted emissions from transportation [94].
	City scale	2020	The environmental benefits documented in major urban agglomerations during the lockdown may extend to medium-sized urban areas as well [95].
Bangladesh	City scale	2021	Due to lockdown measures, significant differences between $PM_{2.5}$, SO_2, NO_2, CO, and O_3 in 2019 and 2020 were observed in Dhaka city. We used lag-0, lag-7, lag-14, and lag-21 days on daily COVID-19 cases to look at the lag effect of different air pollutants on meteorology [25].
	City scale	2021	The concentration of NO_2, $PM_{2.5}$, and SO_2 decreased by about 20%, 26%, and 17.5%, respectively, because of lockdown [38].
	City scale	2021	The concentration of $PM_{2.5}$ and PM_{10} decreased by 40% and 32% during lockdown periods in comparison to previous dry seasons [96].
	Country scale	2020	The concentration of NO_2 and SO_2 decreased by about 40% and 43%, respectively [97].
	City scale	2020	Air quality during lockdown was found to be 5.30% lower than 2019 [98].
Malayasia	Country and City scale	2020	$PM_{.5}$ and PM_{10} decreased by about 25% during lockdown [99].
	City scale	2020	Differences between PM_{10}, $PM_{2.5}$, SO_2, NO_2, CO, O_3, and solar radiation in 2019 and 2020 since the movement control order (MCO) was implemented on 18 March 2020 [100].
Singapore	Country and City scale	2020	The concentrations of the following pollutants PM_{10}, $PM_{2.5}$, NO_2, CO, and SO_2 decreased by 23, 29, 54, 6, and 52%, respectively, while that of O3 increased by 18%. The Pollutant Standards Index decreased by 19% [101].
Korea	City scale	2020	In March 2020, $PM_{2.5}$ showed remarkable reductions of 36% and 30% in Seoul and Daegu, respectively, when compared with the same period from 2017–2019 [102].

	City scale	2020	The $PM_{2.5}$ concentration decreased by about 10.4%, where the average concentration of $PM_{2.5}$ was 23.7% the last 5 years [103].
	Country	2021	The concentration of $PM_{2.5}$, PM_{10}, and NO_2 declined by about 45, 35, and 20%, respectively, because of lockdown [104].
Israel	City scale	2020	In its earlier closest period, the pollution from transport, based on nitrogen oxides, had reduced by 40% on average, whereas the pollution from industry, based on Grand-level ozone had increased by 34% on average [105].
Iran	City scale	2020	$PM_{2.5}$ increased by 0.5–103, 25, and 2–50%. In terms of the national air quality, SO_2 and NO_2 levels decreased, while AOD 26 increased during the lockdown [106].
Pakisthan	Country	2021	There were no significant improvements of air quality in Lahore and Karachi during lockdown periods, as compared to 2019 [107].
	City scale	2021	With the reduction in human activity (known to be the biggest source of air pollution) during the COVID-19 pandemic, changes in air pollution values were observed. The year 2020, compared with 2018 and 2019, in order to observe this change and to compare it with other years: 1 January–15 March, considered the pre-pandemic process; 16 March–31 May, considered the pandemic process; 1 June–30 June, considered the normalization process [108].
	City	2021	During lockdown periods, PM_{10}, $PM_{2.5}$, NO_2, and CO were reduced 32–43%, 19–47%, 29–44% and 40–58%, respectively [109].
Vietnam	City scale	2020	The concentrations of NO_2, $PM_{2.5}$, and SO_2 were reduced by about 75%, 55%, and 67%, respectively [110].
Kazakhstan	City scale	2020	$PM_{2.5}$ declined by 21%, and CO and NO_2 decreased by about 49% and 35%, respectively, during lockdown [111].
Saudi Arabia	Regional	2021	The eastern province of Saudi Arabia reported a reduction in PM_{10}, CO, and SO_2 by 21–70%, 5.8–55%, and 8.7–30%, respectively [112].
Teheran	Country	2020	There were increases in $PM_{2.5}$ and PM_{10} (by 20.5% and 15.7%) during the first month of the COVID-19 outbreak [113].

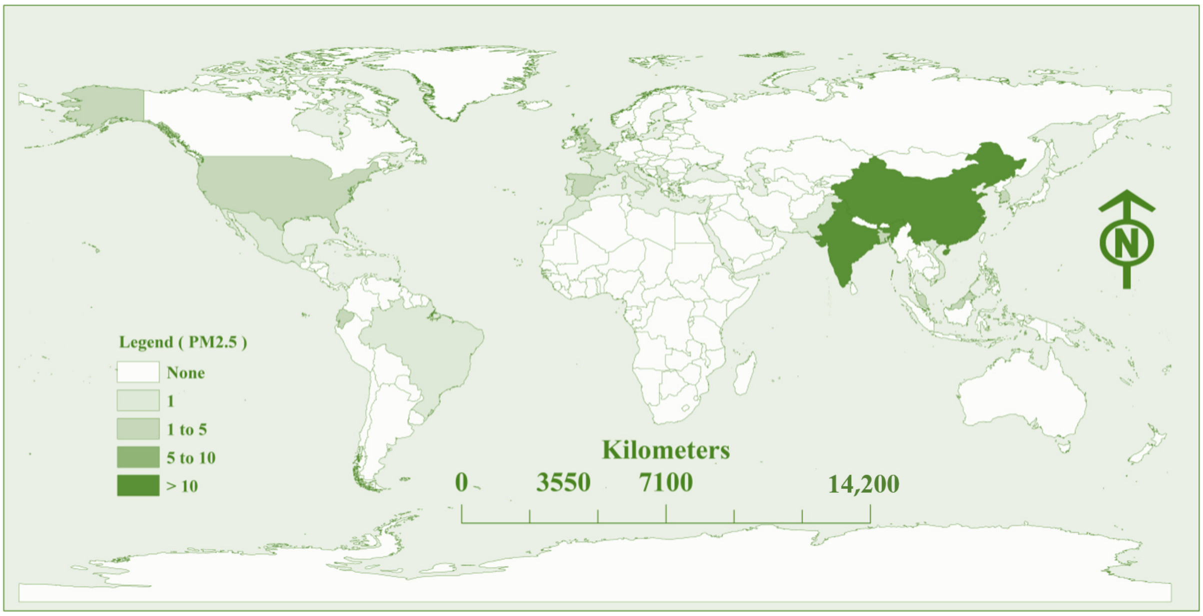

Figure 4. Studies focusing on $PM_{2.5}$ concentrations.

3.3. Impact of COVID-19 on Air Quality over European Countries

After Asia, the second highest number of studies was performed on European countries. As per the literature survey, 33% of the total studies were collected from European countries. In this review, studies were collected from 13 countries in Europe with the highest number of studies on the U.K. (23%), followed by Italy (20%), Spain (20%), Turkey (8.8%), and France (5.5%). The cities in Europe on which studies were performed were Barcelona, Madrid, Naples, the city of Novi Sad, Munich, Tirana, Southampton, and Milan. As per the literature survey, most of the studies were performed on the concentrations of NO_2 (more than 50% of the study). As per the results of Anderson and Dirks [114] (2020), Lee et al. [115], and Jephcote et al. [116], the concentration of NO_2 decreased by about 92%, 42%, and 38%, respectively, in the U.K. Similarly, in Italy, the concentration of NO_2 declined by about 49–62%, and SO_2 decreased by about 70% [117] during lockdown periods. Thus, from the previous studies, it is clear that there was a substantial decline in air pollutants, and air quality significantly improved during lockdown periods. The details of the impact of lockdown on air quality are presented in Table 4. Most of the studies focusing on the concentration of PM_{10} are presented in Figure 5.

Table 4. Literature on the impact of COVID-19 on air quality in European countries.

Country	Scale of Study	Publication Year	Major Findings
UK	England	2021	$PM_{2.5}$ was a major contributor to COVID-19 cases in England, as an increase of 1 m^3 in the long-term average of $PM_{2.5}$ was associated with a 12% increase in COVID-19 cases [118].
	Southampton	2020	NO_2 decreased by about 92% during lockdown, as compared with the previous two years [114].
	Country	2020	NO_2 was reduced by about 42% during lockdown periods [115].
	Country	2021	The concentration of NO_2 and $PM_{2.5}$ concentrations decreased by 38.3% and 16.5%, respectively [116].
	Country	2021	The concentration of NO, NO_2, and NOx decreased 32% to 50% at roadsides during lockdown [119].
	Country	2021	NO_2 concentrations across measurement sites declined by about ~14–38% [120].
	Country	2021	The concentration of NO_2 decreased by about 50%, and O_3 increased by about 10% [121].
	Country	2021	The concentration of Ox emissions declined nationwide by ~20% during the lockdown [122].
Spain	City	2020	The 4-week lockdown had a significant impact on reducing the atmospheric levels of NO_2 in all cities, except for the small city of Santander, as well as the levels of CO, SO_2, and PM_{10} in some cities, but resulted in an increase of the O_3 level [123].
	Country	2020	Changes in the concentration of the pollutant nitrogen dioxide (NO_2) during the lockdown period were examined, as well as how these changes relate to the Spanish population [124].
	City	2021	In 2020, NO_x, NO_2, and NO concentrations decreased by 48.5%–49.8%–46.2%, 62.1%–67.4%–45.7%, 37.4%–35.7%–35.3%, 60.7%–67.7%–47.1%, 65.5%–65.8%–63.5%, 60.0%–64.5%–41.3%, and 60.4%–61.6%–52.5%, respectively [125].
	Country	2021	Decreases in PM10 levels were greater than in PM2.5 because of reduced emissions from road dust, vehicle wear, and construction/dem-

			olition activities. The averaged O_3 daily maximum of 8-h (8hDM) experienced a generalized decrease in the rural receptor sites in the relaxation (June-July) with −20% reduced mobility [20].
	Country	2020	NO_2 was reduced by about 50% during lockdown periods [126].
	City	2020	The concentration of NO_2 in Barcelona and Madrid decreased by about 50% and 62%, respectively, during lockdown periods [127].
Italy	City	2021	NO_2 decreased by about 50%, 34% and 20% from urban traffic, urban backgrounds, and rural backgrounds, respectively [128].
	Regional	2020	Potentially, it is the spatially confounding factors related to urbanization that may have influenced the spreading of novel coronavirus. Our epidemiological analysis uses geographical information (e.g., municipalities) and Poisson regression to assess whether both the ambient PM concentration and the excess mortality have a similar spatial distribution [129].
	Regional	2020	The estimate of the time series slope, i.e., the expected change in the concentration associated with a time unit increase, decreased from −0.25 to −1.67 after the lockdown [130].
	Country	2021	The model finds that there is a positive nonlinear relationship between the density of particulate matter in the air and COVID-19 transmission, which is in alignment with similar studies on other respiratory illnesses [131].
	City	2021	NO_2 was reduced by about 49–62%, and CO and SO_2 declined by about 50–58% and 70%, respectively [117].
	City	2020	There were significant reductions in $PM_{2.5}$, PM_{10}, CO and NO, respectively [21].
	Regional	2021	The concentration of $PM_{2.5}$ and NO_2 declined by about 16% and 33%, respectively [132].
Turkey	Country	2021	To determine the effects of COVID-19 measures on air quality in Turkey, for this investigation, the daily means of PM_{10}, $PM_{2.5}$, NO_2, CO, O_3, and SO_2 air pollutant data were used [133].
	Country	2020	By the end of April, the $PM_{2.5}$ index had improved by about 35% during lockdown [134].
	City	2021	The NO_2 concentrations were reduced by about 11.8 % in the after-virus period [135].
France	Country	2020	Air quality in the Auvergne-Rhône-Alpes region, focusing on nine atmospheric pollutants (NO_2, NO, PM_{10}, $PM_{2.5}$, O_3, VOC, CO, SO_2, and isoprene): In Lyon, the center of the region, the results indicated that NO2, NO, and CO levels were reduced by 67%, 78%, and 62%, respectively, resulting from a decrease in road traffic by 80%. However, O_3, PM_{10}, and $PM_{2.5}$ were increased by 105%, 23%, and 53%, respectively [136].
Russia	City	2020	Just under half were from changes in surface transport. At their peak, emissions in individual countries decreased by –26% on average. The impact on 2020 annual emissions depends on the duration of the confinement, with a low estimate of –4% (–2 to –7%) if pre-pandemic conditions return by mid-June, and a high estimate of –7% (–3 to –13%) [137].
Germany	City	2021	The concentration of NO_2 reduced by about 15–25% and 34–36% from traffic sites during lockdown periods [138].

Macedonia	Country	2020	$PM_{2.5}$ in Kumanovo and carbon monoxide in Skopje (7% and 3% higher concentrations, respectively). The most notable decrement was for NO_2, with a concentration 5–31% lower during the COVID-19 period [139].
Portugal	Country	2021	PM_{10} and NO_2 concentration was reduced by about 18% and 41%, respectively [140].
Netherland	Country	2021	NO_2 and PM_{10} concentration was reduced by about 18–30% and 20%, respectively, during lockdown periods [141].
Poland	Country	2021	Aerosols concentrations were reduced by about 23% and 18% in April and May, respectively [76].
Serbia	City	2021	The average daily concentrations of $PM_{2.5}$, NO_2, PM_{10}, and SO_2 were reduced by 35%, 34%, 23%, and 18%, respectively. In contrast, the average daily concentration of O_3 increased by 8%, even if the primary precursors were reducing, thus representing a challenge for air quality management [142].
Whole Eorope	Europe	2021	Viruses may persist in the air through complex interactions with particles and gases depending on: (1) chemical composition;(2) the electric charges of the particles; and 3) meteorological conditions, such as relative humidity, ultraviolet (UV) radiation, and temperature. In addition, by reducing UV radiation, air pollutants may promote viral persistence in the air and reduce vitamin D synthesis [143].
	Europe	2020	The lockdown effect on atmospheric composition, in particular through massive traffic reductions, has been important for several short-lived atmospheric trace species, with a large reduction in NO_2 concentrations, a lower reduction in particulate matter (PM) concentrations, and a mitigated effect on ozone concentrations due to nonlinear chemical effects [144].
	Europe	2020	The concentration of NO_2 was reduced by about 25% during lockdown periods, when compared to the same periods of previous years [145].

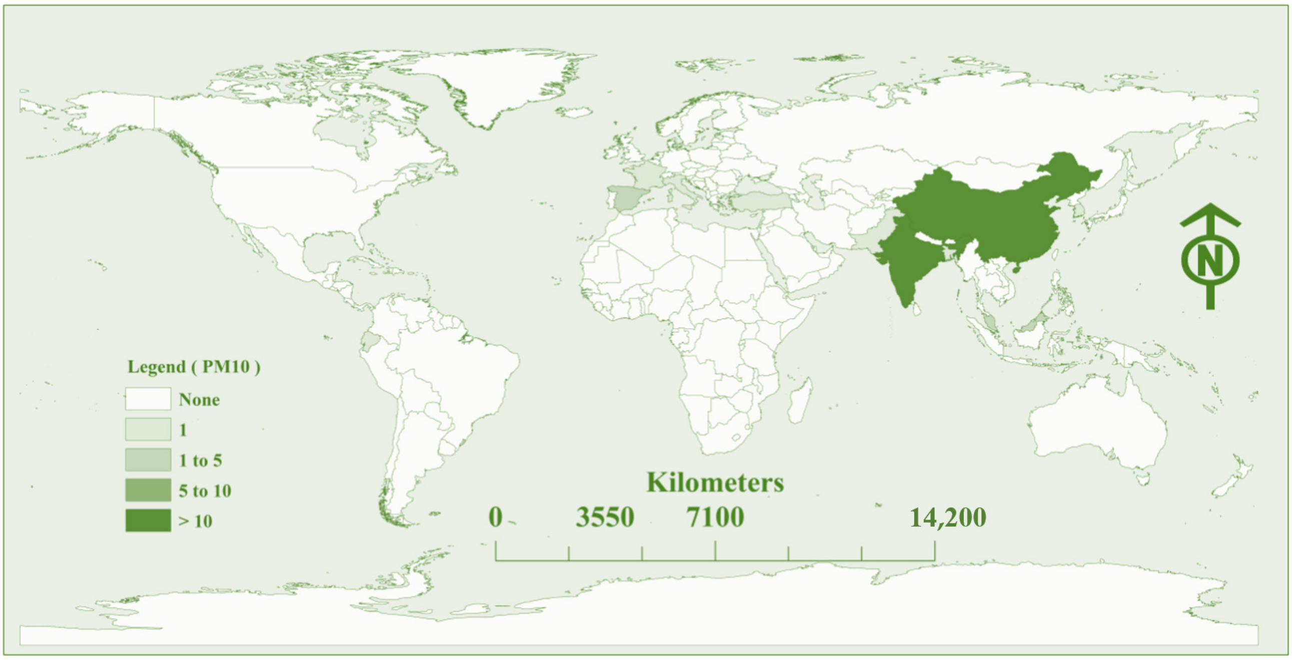

Figure 5. Studies focusing on PM_{10} concentrations.

3.4. Impact of COVID-19 on Air Quality over North American Countries

In North America, the greatest number of studies on air quality were performed on the United States and Canada. In this literature review, about 90% of the total studies were surveyed from the U.S., followed by Canada (10%). Most of the studies in the U.S. were performed at the national level and the city scale (such as California and New Jersey). In the U.S., there were substantial reductions in air pollutants due to lockdown. For example, according to Goldberg et al. [146], NO_2 declined by about 9% to 42%, with the highest decline in San Jose and Los Angeles, and the lowest decrease (<12%) in Miami, Minneapolis, and Dallas. As per the study of Jiang et al. (2020), $PM_{2.5}$ concentration was reduced by more than 68% after lockdown. Moreover, other studies in the U.S. also revealed that there was a significant decrease in the air pollutant concentrations during lockdown periods that resulted in a substantial improvement in air quality (Table 5). The studies focusing on the assessment of CO are shown in Figure 6.

Table 5. Literature on the impact of COVID-19 on air quality in North American countries.

Country	Scale of the Study	Publication Year	Major Findings
US	City	2020	The surface air quality monitoring data from the United States Environmental Protection Agency's (U.S. EPA) AirNow network, during the period from 20 March–5 May in 2020, to the 2015–2019 period, from the Air Quality System (AQS) network over the state of California. The results indicate changes in fine particulate matter (PM2.5) of −2.04 ± 1.57 μg m^{-3} and ozone of −3.07 ± 2.86 ppb. If the air quality improvements persist over a year, it could potentially lead to 3970–8900 preventable premature deaths annually (note: the estimates of preventable premature deaths have large uncertainties). Public transit demand showed dramatic declines (~80%) [147].
	City	2020	COVID-19 prevalence and fatality (plotted as logarithm-transformed prevalence/fatality on the y-axis) as a function of mean ozone/$PM_{2.5}$ AQI (plotted on the x-axis). Coefficients were not statistically significant for ozone (p = 0.212/0.814 for prevalence/fatality) and $PM_{2.5}$ (p = 0.986/0.499) [148].
	Country	2020	The concentration of NO_2 was reduced by about 25% in comparison to past years [149].
	Country	2020	The NO_2 concentration was reduced by about 5 to 49%, with a mixed impact on O_3 (±20%) [24].
	US	2020	NO_2 decreased by about 9–42%, with the highest decreases (>30%) in San Jose and Los Angeles, and the lowest decreases (<12%) in Miami, Minneapolis, and Dallas [146].
	US	2020	$PM_{2.5}$ concentration was reduced by about 68% after lockdown [150].
	City	2020	There were decreases of $PM_{2.5}$ and NO_2 by 36% and 51%, respectively, during lockdown [151].
	City	2021	As per ground-based observation, it was reported that the concentration of NO_2, CO, and $PM_{2.5}$ dropped by about 38%, 49%, and 31%, respectively, during lockdown periods (19 March to 7 May 2020) [152].
Canada	City	2020	The concentration of nitrogen dioxide and nitrogen oxides reduced across Ontario [153].

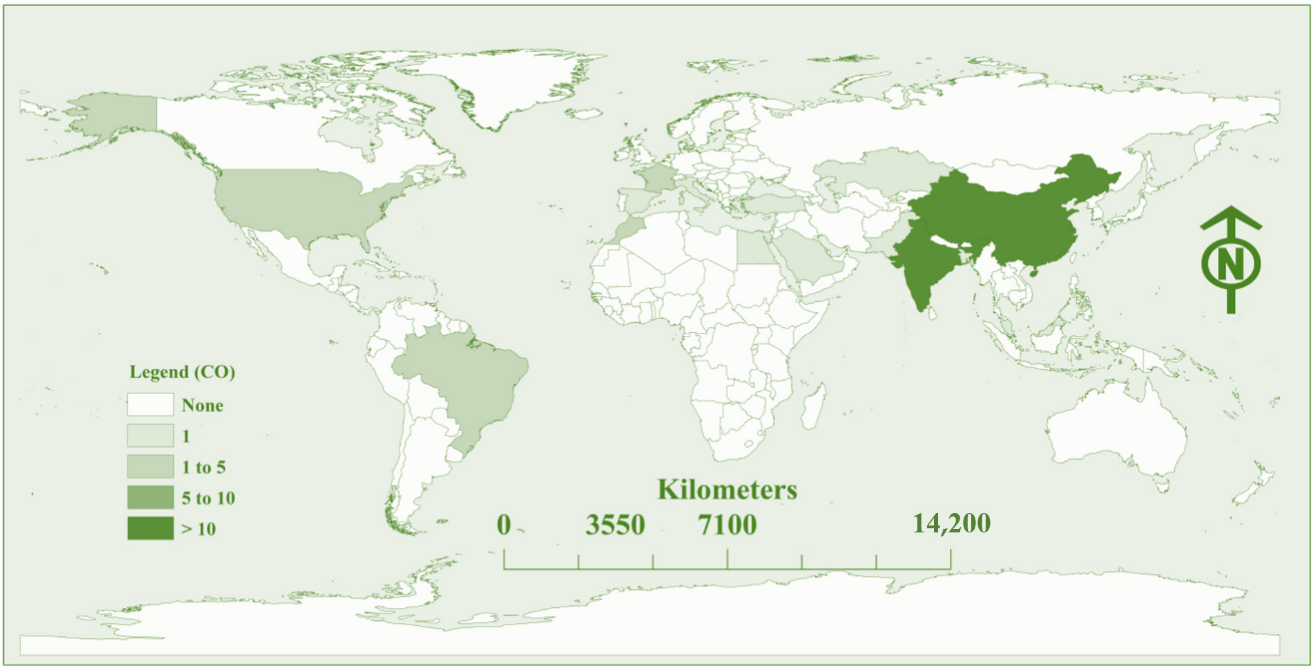

Figure 6. Studies focusing on CO concentrations.

3.5. Impact of COVID-19 on Air Quality over South American Countries

In South America, the greatest number of studies were performed on Brazil, Ecuador, and Mexico. In this review, about 40% of the total studies were surveyed from Brazil and Ecuador, followed by Mexico (20%). As per the results of the study, it was documented that there was a substantial improvement in air quality during lockdown periods. According to Hernández-Paniagua et al. [154], the concentration of NO_2 was reduced by between 10% and 35% in Mexico during lockdown periods. Zalakeviciute et al. [155] performed a study in Quito (Ecuador), and the findings of the study show that air quality improved by about 26% to 68%. According to Nakada and Urban [156], NO, NO_2, and CO decreased by about 70%, 50%, and 60%, respectively, in Sau Paulo (Brazil). The details of the findings on the impact of lockdown on air quality are presented in Table 6. The studies focusing on the assessment of NO_2 are shown in Figure 7.

Table 6. Literature on the impact of COVID-19 on air quality in South American countries.

Country	Scale of the Study	Publication Year	Major Findings
Brazil	City	2020	There was a substantial decrease of NO (more than 70%), CO (more than 60%), and NO_2 (more than 50%). Ozone concentration increased by about 30% during partial lockdown periods, as compared to previous years [11].
	City Scale	2020	Among CO, NO_2, and $PM_{2.5}$, a significant reduction was reported for CO (30–48%) [157].
	City Scale	2020	During lockdown, CO reported the highest decline of up to 100%. NO_2 decreased by about 9 to 41% [158].
Ecuador	City	2020	The concentration of NO_2 and $PM_{2.5}$ significantly decreased due to the implementation of lockdown. The concentration of $PM_{2.5}$ was lower in 2020, as compared to 2018 and 2019 during the same lockdown periods i.e., March [159].
	City	2021	There was a substantial reduction in NO during lockdown periods [160].

	Regional	2020	The concentration of $PM_{2.5}$, PM_{10}, and NO_2 decreased by about 40%, 44% and 60%, respectively, during strict lockdown, and 69%, 58%, and 62%, respectively, during relaxed lockdown periods [155].
	Country	2020	Air quality improved by 29–68% due to lockdown [161].
Maxico	Country	2020	The concentrations of NO_2, SO2, and PM_{10} declined by about 29, 55, and 11%, respectively [154].

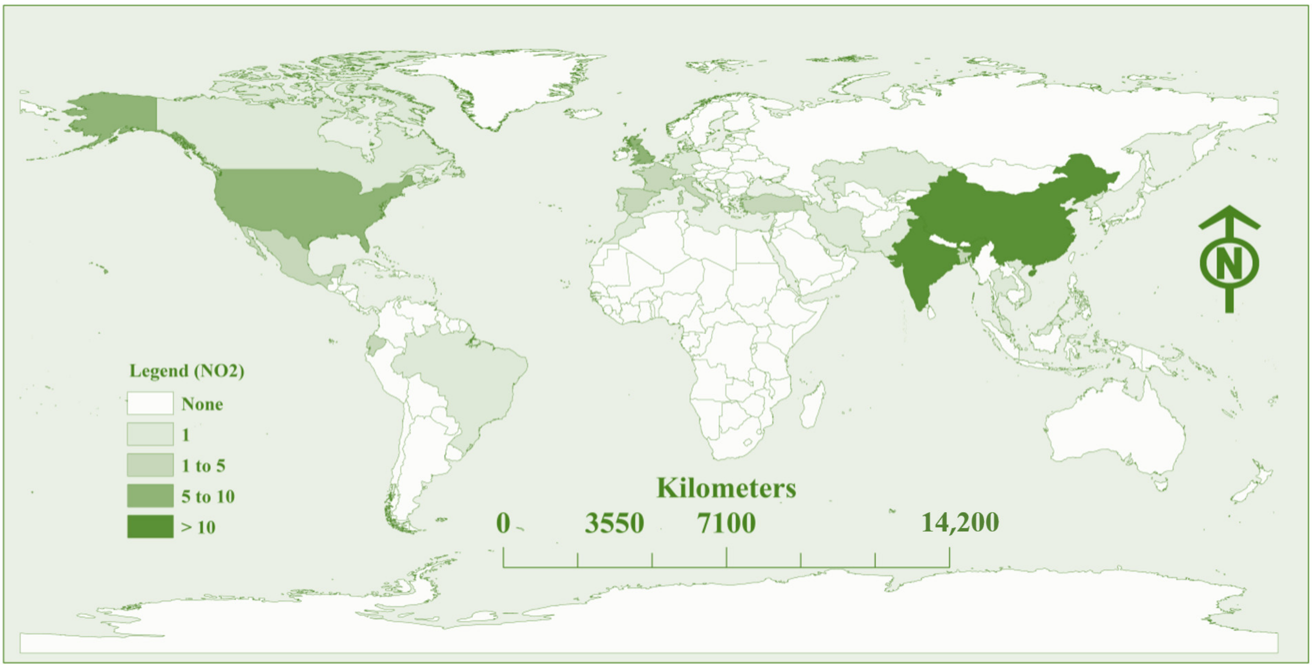

Figure 7. Studies focusing on NO_2 concentrations.

3.6. Impact of COVID-19 on Air Quality over African Countries

In this review, four countries were surveyed from Africa, with the highest percentage of studies on Morocco (42%), followed by Egypt (28%), Uganda (14.3%), and Nigeria (14.3%) (Table 7). In African countries, there were also significant improvements in air quality during lockdown periods. For example, as per the study by Otmani et al. [162], the concentration of $PM_{2.5}$ and PM_{10} decreased by about 75% and 96%, respectively, during lockdown periods. Similarly, CO and NO_2 decreased by about 46% and 45%, respectively. The studies focusing on the assessment of SO_2 are shown in Figure 8.

Table 7. Literature on the impact of COVID-19 on air quality in African countries.

Country	Scale of the Study	Publication Year	Major Findings
Egypt	Country	2020	The whole country is improved as a result of reduced pollutant emissions, with NO_2 reduced by 45.5%, CO emissions reduced by 46.23%, ozone concentration decreased by about 61.1%, and AOD reduced by 68.5%, compared to the previous two years [163].
	City	2021	Absorbing aerosol index (AAI) and NO_2 decreased by about 30% and 15%, respectively, and 33% in Cairo and Alexandria Governorate [22].
Morocco	City Scale	2020	PM_{10} and NO_2 decreased by about 75% and 96%, respectively [164].
Morocco	Country	2020	COVID-19-compelled lockdown may have saved lives by restraining air pollution, thereby preventing infection. We found that NO_2

			dropped by −12 μg/m³ in Casablanca, and by −7 μg/m³ in Marrakech. $PM_{2.5}$ dropped by −18 μg/m³ in Casablanca, and −14 μg/m³ in Marrakech. CO dropped by −0.04 mg/m³ in Casablanca, and −0.12 mg/m³ in Marrakech [165].
Uganda	City Scale	2020	(i) The COVID-19-induced lockdown period. The data has been compared with the same period of the previous year. Promising and notable observations were made in terms of the AQI of Kampala [166].
Nigeria	City Scale	2021	The lockdown resulted in a decrease of SO_2 and NO_2 across the cities. For example, 1.1% and 215.5% of NO_2 and SO_2, respectively, from the city Port Harcourt [167].

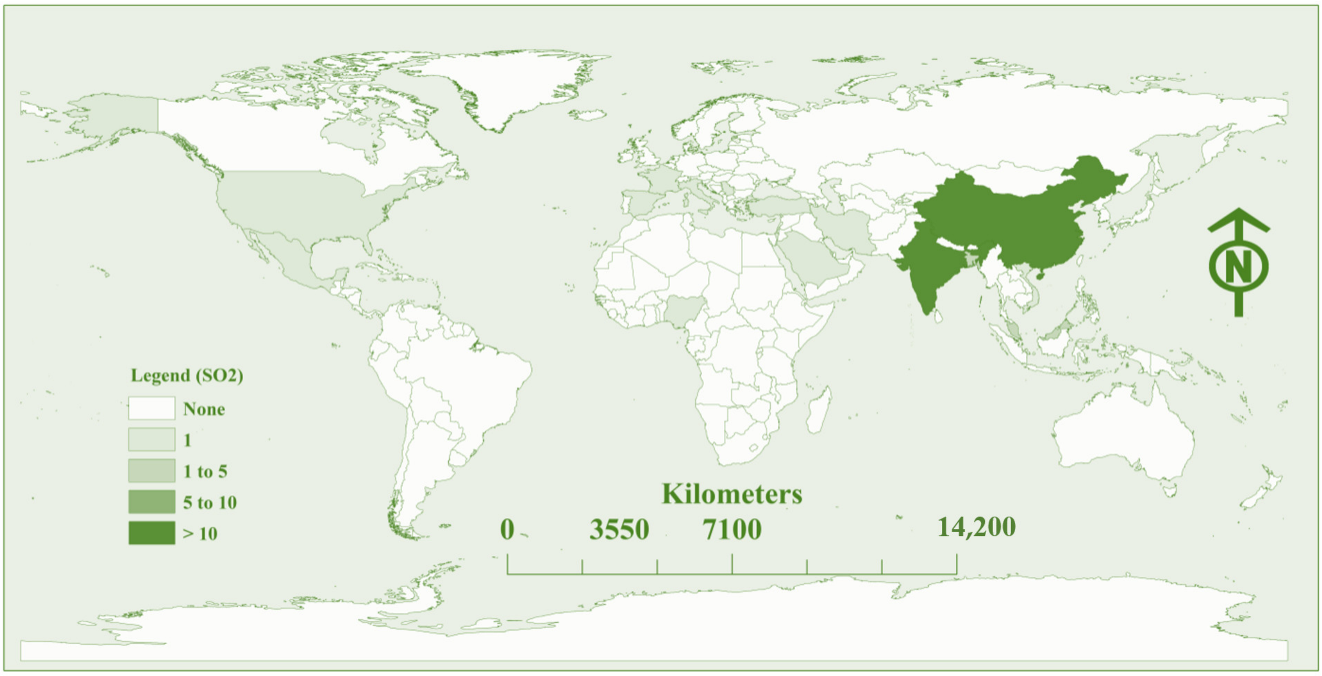

Figure 8. Studies focusing on SO_2 concentration.

3.7. Number of Publications and Journal Distributions

As per literature screening from different sources, it was observed that there were more than 300 studies performed on the impact of lockdown on air quality across the world (as per our observations from April 2020 to March 2021). Among all the countries, the greatest number of studies were performed on Asian countries, followed by European countries. From the literature screening, it was well-recognized that the greatest number of research studies were published by Science of The Total Environment (about 29%), followed by Aerosol and Air Quality Research (23%), Air Quality, Atmosphere & Health (9%), Environmental Pollution (6%), and Environmental Research (4%). From the top ten journals, about 80% of the total studies were included (Figures 9 and 10).

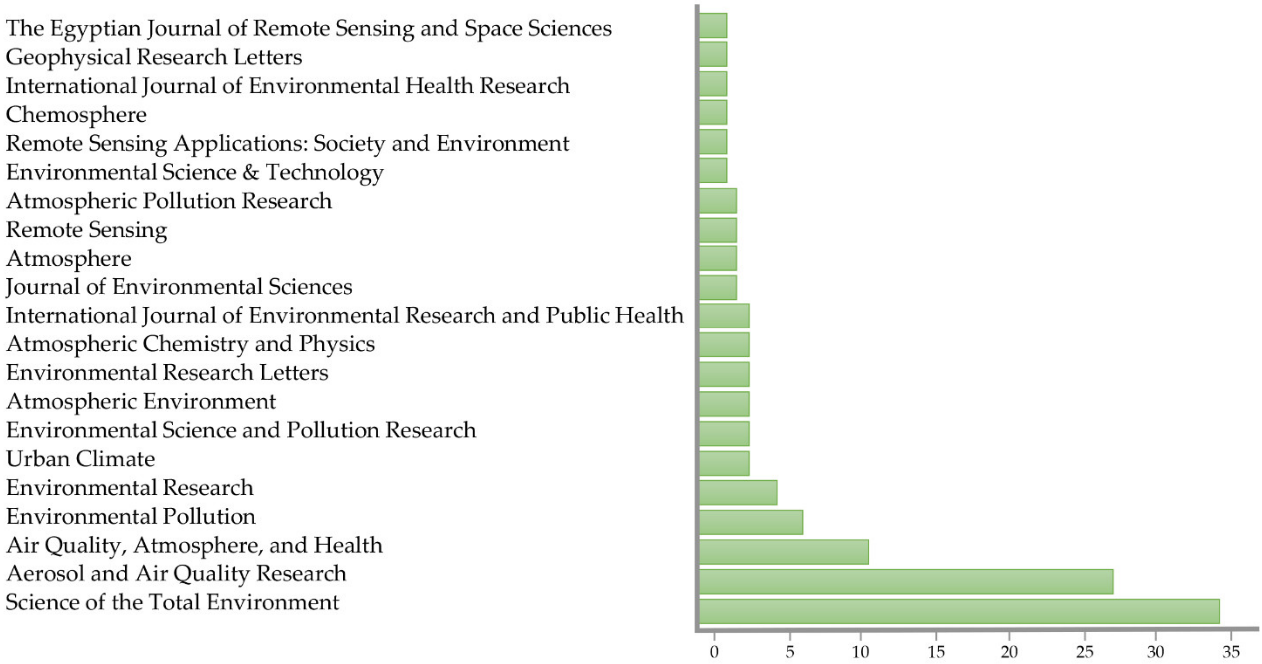

Figure 9. Contribution of major journals as per the literature screening (%).

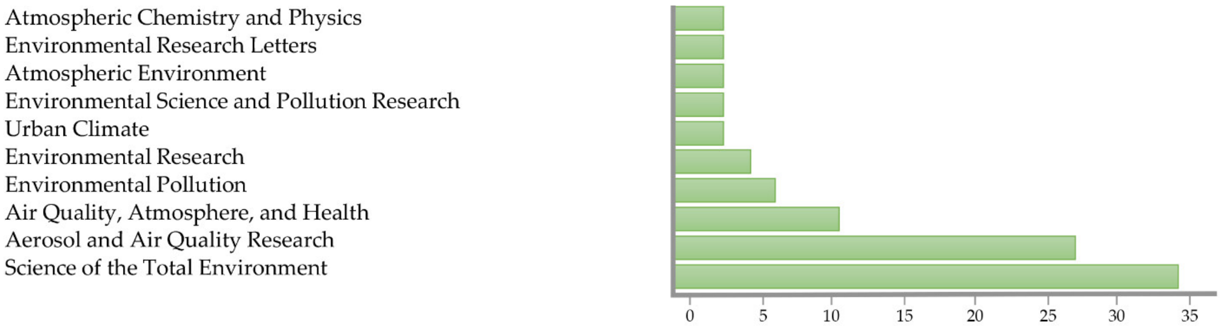

Figure 10. Top 10 journals as per the literature screening (%).

4. Discussion

The present study mainly focuses on a review on the impact of COVID-19 lockdowns on air quality around the globe. From the results, it was found that most of the studies on the impact of lockdowns on air quality were performed in Asian countries (about 65%), followed by European countries (18%), and North and South American countries (10%). As per the literature screening, it was reported that the greatest number of studies on the impact of lockdown on air quality were reported from India (29%), followed by China (23%), the U.K. (4.44%), and Italy (3.89%). From the previous research studies, it was recognized that there was a strong association between air pollutants and respiratory disease [168–170]. Thus, the areas with high exposure to air pollution are vulnerable to mortalities due to respiratory diseases. With COVID-19 being a respiratory disease, it is obvious that COVID-19 deaths are strongly influenced by air pollutants. Recent studies also show that the concentrations of air pollutants are significant risk factors in COVID-19 deaths [171–174]. In many studies across the cities of the world, it is reported that concentrations of air pollutants are strongly associated with COVID-19 cases, as well as deaths. The severely affected countries of the world imposed several measures to fight COVID-19 and reduce the transmission of the virus around the world [47]. China was the first country to implement a complete shutdown in commercial fields, restrictions on domestic and international travel, and strict COVID-19 protocols were imposed across affected cities [175]. After that, similar restrictions were implemented by several other countries, such as India, Italy, and France. These restrictions were placed on public transportation, social gatherings, schools and colleges, and emissions from industries as well (Das et al., 2020). Economic activities are the prime factors that contribute to environmental pollution because of the combustion of fuel and the release of air pollutants into the atmosphere [175]. In most of the densely populated cities, particularly the ones in developing countries, air pollution levels are higher than the tolerance limits, and that results in risks to human health. In urban areas, the concentration of primary air pollutants, such as CO, NO_2, SO_2, O_3 are significantly higher. The concentrations of particulate matters ($PM_{2.5}$ and PM_{10}) were significantly decreased during lockdown periods due to the restriction on emissions from various sources [18]. A substantial improvement in air quality was reported for most polluted cities around the world, such as Delhi (the capital city of India, India), Dhaka (the capital city of Bangladesh), and Beijing (China). Thus, COVID-19 lockdowns have had positive impacts on the environment. Therefore, from the overall results, it can be stated that lockdown, particularly short-term lockdown, can, to some extent, be considered an alternative measure to reduce air pollution level. The outbreak of COVID-19 compelled the affected countries to impose lockdowns to curb COVID-19 transmission, and many countries have remained under partial lockdown since last year. Thus, the environment has had a long time to restore its capacity because of the cessation of many economic activities. However, in reality, it is not possible to completely cease economic activity because it is a matter of human livelihoods. So, planners and policymakers must implement and follow sustainable strategies to reduce air pollution levels. The lockdowns during COVID-19 not only induced the improvement of air quality, but it has also had other positive effects on the environment. Measures regarding social distancing kept people away from resorts and sea beaches, and effluent discharge into the water stopped because of industrial shutdowns. Water quality also improved in many countries, such as in Spain, Equador, and Mexico. For instance, as per the findings of Paital et al. (2020), and Saadat et al. (2020), the water quality of Venice’s canals, and the Yamuna River in Delhi, improved significantly in comparison with past years. Apart from environmental perfectives, COVID-19 lockdowns also had a substantial impact on the global economy. As per a World Trade Organization (WTO, 2020) report, economic activity decreased in world trade between 13% and 32%. Thus, it has been well-documented in previous literature that COVID-19 lockdowns result in substantial positive, as well as negative, impacts on the environment.

The present review study on the impact of COVID-19 lockdowns on air quality across the globe can provide a unique work for understanding, as well as implementing, effective strategies at the city, regional, and country scales. For example, among all the regions, Asian countries, such as India, China, and Bangladesh, are more severely affected by extreme air pollution levels. At the country scale, most of the studies were performed in India, followed by China, and the U.K. Thus, at the global scale, effective strategies can be implemented for the Asian region to fight air pollution levels, and at the country scale (such as with India), cities can be identified through this literature and strategies for them can thus be implemented. Therefore, this study may be very helpful to planners and policymakers for understanding the global scenario and the improvement of air quality due to COVID-19 lockdowns. In this study, few limitations can be identified. Firstly, in this study, the literature was reviewed from March 2020 to April 2021. No studies were taken into consideration that were published after April 2021 in this review assessment. Thus, further research in the future can be performed on literature published after April 2021 for a better understanding of the impact of lockdown on air quality. Secondly, no models or laws were applied in this study for literature screening. Thus, for future researchers, we suggest implementing the Bradford law for literature screening. In spite of these limitations of the study, this is a unique piece of research into the global scenario with respect to the impact of COVID-19 lockdowns on air quality.

5. Conclusions

In this study, an attempt has been made to examine and review the impact of COVID-19 lockdowns on air quality on a global scale. Initially, 237 studies related to the impact of COVID-19 lockdowns on air quality were screened, and 144 studies were finally taken into account for this literature review. The literature was extracted from Scopus, Google Scholar, PubMed, Web of Science, and the Google search engine. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) was also used for the literature screening. As per the results of this study, it is well-documented that most of the studies were performed over the Asian region (65%), followed by Europe (18%), North America (6%), South America (5%), and Africa (3%). At the country scale, the greatest number of studies were conducted in India (29%), followed by China (23%), the U.S. (5%), the UK (4%), and Italy. As per our investigation, it was observed that the greatest number of studies on the impact of the COVID-19 pandemic on air quality was published in *Science of the Total Environment* (29%), followed by *Aerosol and Air Quality Research* (23%), *Air Quality, Atmosphere & Health* (9%), and *Environmental Pollution* (5%). From the core findings of the literature, it is apparent that there was substantial improvement in air quality due to lockdowns across the world. For example, Naqvi et al. [19] performed a study on India and reported that the air quality index was reduced by about 40% during one month of lockdown. According to Filonchyk et al. [76], and Diamond and Wood [82], the concentrations of CO and NO_2 were reduced by about 20% and 30%, respectively, and by 50% in China. In the U.K., NO_2 was reduced by about 42% during lockdown periods [107]. Thus, in all of the countries, it has been well-recognized that there was a substantial improvement in air quality during the lockdowns. The implementation of lockdowns around the world resulted in the improvement of the air quality and provided us with an opportunity to realize the impact of the anthropogenic pressures on the environment. Thus, the findings of the review will surely assist planners and policymakers to understand that the implementation of lockdowns may be an effective measure to restore the environment, and to build quality ecosystems in urban environments. All the affected countries of the world imposed effective measures to try to slow down the transmission of COVID-19. These measures included the closures of industrial activities, strict restrictions on transportation, and the cessation of other productive activities that resulted in the improvement of air quality.

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Reference

1. World Health Organization. *World Health Statistics 2016: Monitoring Health for the SDGs Sustainable Development Goals*; World Health Organization: Switzerland, 2016.
2. Anenberg, S.; Horowitz, L.; Tong, D.; West, J.J. An Estimate of the Global Burden of Anthropogenic Ozone and Fine Particulate Matter on Premature Human Mortality Using Atmospheric Modeling. *Environ. Health Perspect.* **2010**, *118*, 1189–1195, doi:10.1289/ehp.0901220.

3. Krewski, D.; Jerrett, M.; Burnett, R.T.; Ma, R.; Hughes, E.; Shi, Y.; Turner, M.; Pope, C.; Thurston, G.; Calle, E.; Tempalski, B. *Extended Follow-Up and Spatial Analysis of the American Cancer Society Study Linking Particulate Air Pollution and Mortality*; Health Effects Institute: Boston, MA, USA, 2009; pp. 5–114.
4. Slama, R.; Darrow, L.; Parker, J.; Woodruff, T.J.; Strickland, M.; Nieuwenhuijsen, M.; Glinianaia, S.; Hoggatt, K.; Kannan, S.; Hurley, F.;…Ritz, B. Meeting Report: Atmospheric Pollution and Human Reproduction. *Environ. Health Perspect.* **2008**, *116*, 791–798, doi:10.1289/ehp.11074.
5. Smith, K.R.; Bruce, N.; Balakrishnan, K.; Adair-Rohani, H.; Balmes, J.; Chafe, Z.; Dherani, M.; Hosgood, H.; Mehta, S.; Pope, D.; Rehfuess, E. Millions dead: How do we know and what does it mean? Methods used in the comparative risk assessment of household air pollution. *Annu. Rev. Public Health* **2014**, *35*, 185–206.
6. Pedersen, M.; Giorgis-Allemand, L.; Bernard, C.; Aguilera, I.; Andersen AM, N.; Ballester, F.; Beelen, R.; Chatzi, L.; Cirach, M.; Danileviciute, A.; Dedele, A.; Eijsden, M.; Estarlich, M.; Fernández-Somoano, A.; Slama, R. Ambient air pollution and low birthweight: A European cohort study (ESCAPE). *Lancet Respir. Med.* **2013**, *1*, 695–704.
7. Pope, C.A.; Rodermund, D.L.; Gee, M.M. Mortality Effects of a Copper Smelter Strike and Reduced Ambient Sulfate Particulate Matter Air Pollution. *Environ. Health Perspect.* **2007**, *115*, 679–683, doi:10.1289/ehp.9762.
8. Sun, Z.; Yang, L.; Bai, X.; Du, W.; Shen, G.; Fei, J.; Wang, Y.; Chen, A.; Chen, Y.; Zhao, M. Maternal ambient air pollution exposure with spatial-temporal variations and preterm birth risk assessment during 2013–2017 in Zhejiang Province, China. *Environ. Int.* **2019**, *133*, 105242, doi:10.1016/j.envint.2019.105242.
9. Weinmayr, G.; Hennig, F.; Fuks, K.; Nonnemacher, M.; Jakobs, H.; Möhlenkamp, S.; Erbel, R.; Jöckel, K.; Hoffmann, B.; Moebus, S.;… Nixdorf, H. Long-term exposure to fine particulate matter and incidence of type 2 diabetes mellitus in a cohort study: Effects of total and traffic-specific air pollution. *Environ. Health* **2015**, *14*, 1–8.
10. GBD. The Global Burden of Disease, 2018, GBD. In *The Global Burden of Disease. Generating Evidence and Guiding Policy*; Institute for Health Metrics and Evaluation: Seattle, WA, USA, 2018.
11. Dantas, G.; Siciliano, B.; França, B.B.; da Silva, C.M.; Arbilla, G. The impact of COVID-19 partial lockdown on the air quality of the city of Rio de Janeiro, Brazil. *Sci. Total Environ.* **2020**, *729*, 139085, doi:10.1016/j.scitotenv.2020.139085.
12. Ibe, F.C.; Opara, A.I.; Duru, C.E.; Obinna, I.B.; Enedoh, M.C. Statistical analysis of atmospheric pollutant concentrations in parts of Imo State, Southeastern Nigeria. *Sci. Afr.* **2020**, *7*, e00237.
13. Otmani, A.; Benchrif, A.; Tahri, M.; Bounakhla, M.; Chakir, E.M.; El Bouch, M.; Krombi, M. Impact of Covid-19 lockdown on PM10, SO2 and NO2 concentrations in Salé City (Morocco). *Sci. Total Environ.* **2020**, *735*, 139541, doi:10.1016/j.scitotenv.2020.139541.
14. Tobías, A.; Carnerero, C.; Reche, C.; Massagué, J.; Via, M.; Minguillón, M.C.; Via, M.; Minguillón, M.; Alastuey, A.; Querol, X. Changes in air quality during the lockdown in Barcelona (Spain) one month into the SARS-CoV-2 epidemic. *Sci. Total Environ.* **2020**, *726*, 138540.
15. Nigam, R.; Pandy, K.; Luis, A.; Sengupta, R.; Kotha M. Positive effects of COVID-19 lockdown on air quality of industrial cities (Ankleshwar and Vapi) of Western India. *Sci. Rep.* **2021**, *11*, 4285, doi.org/10.1038/s41598-021-83393-9.
16. Navinya, C., Patidar, G. and Phuleria, H.C. Examining effects of the COVID-19 national lockdown on ambient air quality across urban India. *Aerosol Air Qual. Res.* **2020**, *20*, 1759–1771.
17. Sikarwar, A.; Rani, R. Assessing the Immediate Effect of Covid-19 Lockdown on Air Quality: A Case Study of Delhi, India. *J. Environ. Geogr.* **2020**, *13*, 27–33, doi:10.2478/jengeo-2020-0009.
18. Singh, R.P.; Chauhan, A. Impact of lockdown on air quality in India during COVID-19 pandemic. *Air Qual. Atmos. Health* **2020**, *13*, 921–928, doi:10.1007/s11869-020-00863-1.
19. Zhang, J., Cui, K., Wang, Y. F., Wu, J. L., Huang, W. S., Wan, S. and Xu, K. Temporal Variations in the Air Quality Index and the Impact of the COVID-19 Event on Air Quality in Western China. *Aerosol Air Qual. Res.* **2020**, *20*, 1552–1568. https://doi.org/10.4209/aaqr.2020.06.0297
20. Querol, X.; Massagué, J.; Alastuey, A.; Moreno, T.; Gangoiti, G.; Mantilla, E.; Duéguez, J.; Escudero, M.; Monfortf, E.; García-Pando, C.; Cornide, M.J. Lessons from the COVID-19 air pollution decrease in Spain: Now what? *Sci. Total Environ.* **2021**, *779*, 146380, doi:10.1016/j.scitotenv.2021.146380.
21. Collivignarelli, M.C.; Abbà, A.; Bertanza, G.; Pedrazzani, R.; Ricciardi, P.; Miino, M.C. Lockdown for CoViD-2019 in Milan: What are the effects on air quality? *Sci. Total Environ.* **2020**, *732*, 139280.
22. Mostafa, M.K.; Gamal, G.; Wafiq, A. The impact of COVID 19 on air pollution levels and other environmental indicators—A case study of Egypt. *J. Environ. Manag.* **2021**, *277*, 111496, doi:10.1016/j.jenvman.2020.111496.
23. Singh, V.; Singh, S.; Biswal, A.; Kesarkar, A.P.; Mor, S.; Ravindra, K. Diurnal and temporal changes in air pollution during COVID-19 strict lockdown over different regions of India. *Environ. Pollut.* **2020**, *266*, 115368, doi:10.1016/j.envpol.2020.115368.
24. Chen, L.-W.A.; Chien, L.-C.; Li, Y.; Lin, G. Nonuniform impacts of COVID-19 lockdown on air quality over the United States. *Sci. Total Environ.* **2020**, *745*, 141105, doi:10.1016/j.scitotenv.2020.141105.
25. Islam, S.; Rahman, M.; Tusher, T.R.; Roy, S.; Razi, M.A. Assessing the Relationship between COVID-19, Air Quality, and Meteorological Variables: A Case Study of Dhaka City in Bangladesh. *Aerosol Air Qual. Res.* **2021**, *21*, 200609, doi:10.4209/aaqr.200609.
26. Muhammad, S.; Long, X.; Salman, M. COVID-19 pandemic and environmental pollution: A blessing in disguise? *Sci. Total Environ.* **2020**, *728*, 138820, https://doi.org/10.1016/j.scitotenv.2020.138820.
27. Wang, Q.; Su, M. A preliminary assessment of the impact of COVID-19 on environment—A case study of China. *Sci. Total Environ.* **2020**, *728*, 138915, doi:10.1016/j.scitotenv.2020.138915.

28. Saadat, S.; Rawtani, D.; Hussain, C.M. Environmental perspective of COVID-19. *Sci. Total Environ.* **2020**, *728*, 138870, doi:10.1016/j.scitotenv.2020.138870.
29. NASA. Airborne Nitrogen Dioxide Plummets over China. 2020. Available online: https://earthobservatory.nasa.gov/images/146362/airborne-nitrogen-dioxide-plummets-over-china (accessed on 28 April 2020).
30. Moher, D.; Liberati, A.; Tetzlaff, J.; Altman, D.G.; The PRISMA Group. Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. *PLoS Med.* **2009**, *6*, e1000097, doi:10.1371/journal.pmed.1000097.
31. Naqvi, H.R.; Datta, M.; Mutreja, G.; Siddiqui, M.A.; Naqvi, D.F.; Naqvi, A.R. Improved air quality and associated mortalities in India under COVID-19 lockdown. *Environ. Pollut.* **2021**, *268*, 115691, doi:10.1016/j.envpol.2020.115691.
32. Mor, S.; Kumar, S.; Singh, T.; Dogra, S.; Pandey, V.; Ravindra, K. Impact of COVID-19 lockdown on air quality in Chandigarh, India: Understanding the emission sources during controlled anthropogenic activities. *Chemosphere* **2021**, *263*, 127978, doi:10.1016/j.chemosphere.2020.127978.
33. Eregowda, T.; Chatterjee, P.; Pawar, D.S. Impact of lockdown associated with COVID19 on air quality and emissions from transportation sector: Case study in selected Indian metropolitan cities. *Environ. Syst. Decis.* **2021**, *41*, 401–412, doi:10.1007/s10669-021-09804-4.
34. Mahato, S.; Pal, S.; Ghosh, K.G. Effect of lockdown amid COVID-19 pandemic on air quality of the megacity Delhi, India. *Sci. Total Environ.* **2020**, *730*, 139086, doi:10.1016/j.scitotenv.2020.139086.
35. Bedi, J.S.; Dhaka, P.; Vijay, D.; Aulakh, R.S.; Gill, J.P.S. Assessment of Air Quality Changes in the Four Metropolitan Cities of India during COVID-19 Pandemic Lockdown. *Aerosol Air Qual. Res.* **2020**, *20*, 2062–2070, doi:10.4209/aaqr.2020.05.0209.
36. Shehzad, K.; Sarfraz, M.; Shah, S.G.M. The impact of COVID-19 as a necessary evil on air pollution in India during the lockdown. *Environ. Pollut.* **2020**, *266*, 115080, doi:10.1016/j.envpol.2020.115080.
37. Gautam, S. COVID-19: Air pollution remains low as people stay at home. *Air Qual. Atmos. Health* **2020**, *13*, 853–857, doi:10.1007/s11869-020-00842-6.
38. Rahman, S.; Azad, A.K.; Hasanuzzaman; Salam, R.; Islam, A.R.M.T.; Rahman, M.; Hoque, M.M.M. How air quality and COVID-19 transmission change under different lockdown scenarios? A case from Dhaka city, Bangladesh. *Sci. Total Environ.* **2021**, *762*, 143161, doi:10.1016/j.scitotenv.2020.143161.
39. Mitra, A.; Chaudhuri, T.R.; Mitra, A.; Pramanick, P.; Zaman, S.; Mitra, A.; Zaman, S. Impact of COVID-19 related shutdown on atmospheric carbon dioxide level in the city of Kolkata. *Parana J. Sci. Educ.* **2020**, *6*, 84–92.
40. Roy, S.S.; Balling, R.C. Impact of the COVID-19 lockdown on air quality in the Delhi Metropolitan Region. *Appl. Geogr.* **2021**, *128*, 102418, doi:10.1016/j.apgeog.2021.102418.
41. Goel, A. Impact of the COVID-19 Pandemic on the Air Quality in Delhi, India. *Nat. Environ. Pollut. Technol.* **2020**, *19*, 1095–1103, doi:10.46488/nept.2020.v19i03.020.
42. Chakrabortty, R.; Pal, S.C.; Ghosh, M.; Arabameri, A.; Saha, A.; Roy, P.; Pradhan, B.; Mondal, A.; Ngo, P.; Chowdhuri, I.; Das, B. Weather indicators and improving air quality in association with COVID-19 pandemic in India. *Soft Comput.* **2021**, 25, 1–22, doi:10.1007/s00500-021-06012-9.
43. Das, M.; Das, A.; Sarkar, R.; Saha, S.; Mandal, A. Examining the impact of lockdown (due to COVID-19) on ambient aerosols (PM 2.5): A study on Indo-Gangetic Plain (IGP) Cities, India. *Stoch. Environ. Res. Risk Assess.* **2021**, *35*, 1301–1317, doi:10.1007/s00477-020-01905-x.
44. Das, M.; Das, A.; Ghosh, S.; Sarkar, R.; Saha, S. Spatio-temporal concentration of atmospheric particulate matter (PM2. 5) during pandemic: A study on most polluted cities of indo-gangetic plain. *Urban Clim.* **2021**, *35*, 100758.
45. Das, M.; Das, A.; Sarkar, R.; Saha, S.; Mandal, P. Regional scenario of air pollution in lockdown due to COVID-19 pandemic: Evidence from major urban agglomerations of India. *Urban Clim.* **2021**, *37*, 100821, doi:10.1016/j.uclim.2021.100821.
46. Aman, M.A.; Salman, M.S.; Yunus, A.P. COVID-19 and its impact on environment: Improved pollution levels during the lockdown period—A case from Ahmedabad, India. *Remote. Sens. Appl. Soc. Environ.* **2020**, *20*, 100382, doi:10.1016/j.rsase.2020.100382.
47. Biswal, A.; Singh, V.; Singh, S.; Kesarkar, A.P.; Ravindra, K.; Sokhi, R.S.; Chipperfield, M.; Dhomse, S.; Pope, R.; Singh, T.; Mor, S. COVID-19 lockdown-induced changes in NO 2 levels across India observed by multi-satellite and surface observations. *Atmos. Chem. Phys.* **2021**, *21*, 5235–5251.
48. Biswas, M.S.; Choudhury, A.D. Impact of COVID-19 Control Measures on Trace Gases (NO2, HCHO and SO2) and Aerosols over India during Pre-monsoon of 2020. *Aerosol Air Qual. Res.* **2021**, *21*, 200306.
49. Datta, A.; Rahman, H.; Suresh, R. Did the COVID-19 lockdown in Delhi and Kolkata improve the ambient air quality of the two cities? *J. Environ. Qual.* **2021**, *50*, 485–493, doi:10.1002/jeq2.20192.
50. Dhaka, S.K.; Kumar, V.; Panwar, V.; Dimri, A.P.; Singh, N.; Patra, P.K.; Matsumi, Y.; Takigawa, M.; Nakayama, T.; Hayashida, S. PM 2.5 diminution and haze events over Delhi during the COVID-19 lockdown period: An interplay between the baseline pollution and meteorology. *Sci. Rep.* **2020**, *10*, 1–8.
51. Dutta, A.; Jinsart, W. Air Quality, Atmospheric Variables and Spread of COVID-19 in Delhi (India): An Analysis. *Aerosol Air Qual. Res.* **2021**, *21*, 200417.
52. Siddiqui, A.; Halder, S.; Chauhan, P.; Kumar, P. COVID-19 Pandemic and City-Level Nitrogen Dioxide (NO2) Reduction for Urban Centres of India. *J. Indian Soc. Remote. Sens.* **2020**, *48*, 1–8, doi:10.1007/s12524-020-01130-7.
53. Sharma, S.; Zhang, M.; Gao, J.; Zhang, H.; Kota, S.H. Effect of restricted emissions during COVID-19 on air quality in India. *Sci. Total Environ.* **2020**, *728*, 138878, https://doi.org/10.1016/j.scitotenv.2020.139542.

54. Jain, S.; Sharma, T. 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.* **2020**, *20*, 1222–1236, doi:10.4209/aaqr.2020.04.0171.
55. Kumar, P.; Hama, S.; Omidvarborna, H.; Sharma, A.; Sahani, J.; Abhijith, K.V.; Debele, S.; Zavala-Reyes, J.; Barwise, Y.; Tiwari, A. Temporary reduction in fine particulate matter due to 'anthropogenic emissions switch-off' during COVID-19 lockdown in Indian cities. *Sustain. Cities Soc.* **2020**, *62*, 102382.
56. Kumari, P.; Toshniwal, D. Impact of lockdown measures during COVID-19 on air quality–A case study of India. *Int. J. Environ. Health Res.* **2020**, 31, 1–8, https://doi.org/10.1080/09603123.2020.1778646.
57. Lal, P.; Kumar, A.; Bharti, S.; Saikia, P.; Adhikari, D.; Khan, M. Lockdown to Contain the COVID-19 Pandemic: An Opportunity to Create a Less Polluted Environment in India. *Aerosol Air Qual. Res.* **2021**, *21*, 200229, doi:10.4209/aaqr.2020.05.0229.
58. Garg, A.; Kumar, A.; Gupta, N.C. Impact of Lockdown on Ambient Air Quality in COVID-19 Affected Hotspot Cities of India: Need to Readdress Air Pollution Mitigation Policies. *Environ. Claims J.* **2021**, *33*, 65–76, doi:10.1080/10406026.2020.1822615.
59. Yuan, Q.; Qi, B.; Hu, D.; Wang, J.; Zhang, J.; Yang, H.; Zhang S.; Liu, L.; Xu, L.; Li, W. Spatiotemporal variations and reduction of air pollutants during the COVID-19 pandemic in a megacity of Yangtze River Delta in China. *Sci. Total Environ.* **2021**, *751*, 141820, doi:10.1016/j.scitotenv.2020.141820.
60. Zheng, H.; Kong, S.; Chen, N.; Yan, Y.; Liu, D.; Zhu, B.; Xu, K.; Cao, W.; Ding, Q.; Lan, B.; Qi, S. Significant changes in the chemical compositions and sources of PM2.5 in Wuhan since the city lockdown as COVID-19. *Sci. Total Environ.* **2020**, *739*, 140000, doi:10.1016/j.scitotenv.2020.140000.
61. He, G.; Pan, Y.; Tanaka, T. The short-term impacts of COVID-19 lockdown on urban air pollution in China. *Nat. Sustain.* **2020**, *3*, 1005–1011, doi:10.1038/s41893-020-0581-y.
62. Ji, J.; Chang, R. Air quality changes and Grey relational analysis of pollutants exceeding standards during the COVID-19 pandemic in Wuhan. *Res. Sq.* **2020**, https://doi.org/10.21203/rs.3.rs-34041/v3.
63. Miller, P.; Reesman, C.; Grossman, M.; Nelson, S.; Liu, V.; Wang, P. Marginal warming associated with a COVID-19 quarantine and the implications for disease transmission. *Sci. Total Environ.* **2021**, *780*, 146579, doi:10.1016/j.scitotenv.2021.146579.
64. Wang, N.; Xu, J.; Pei, C.; Tang, R.; Zhou, D.; Chen, Y.; Li, M.; Deng, X.; Deng, T.; Huang, X.; Ding, A. Air Quality During COVID-19 Lockdown in the Yangtze River Delta and the Pearl River Delta: Two Different Responsive Mechanisms to Emission Reductions in China. *Environ. Sci. Technol.* **2021**, *55*, 5721–5730, doi:10.1021/acs.est.0c08383.
65. Feng, H.; Ning, E.; Feng, H.; Li, J.; Wang, Q. Impact of COVID-19 on Air Quality in Central and Eastern China. *Res. Sq.* **2021**, https://doi.org/10.21203/rs.3.rs-251180/v1.
66. Ming, W.; Zhou, Z.; Ai, H.; Bi, H.; Zhong, Y. COVID-19 and Air Quality: Evidence from China. *Emerg. Mark. Finance Trade* **2020**, *56*, 2422–2442, doi:10.1080/1540496x.2020.1790353.
67. Zhang, K.; De Leeuw, G.; Yang, Z.; Chen, X.; Jiao, J. The Impacts of the COVID-19 Lockdown on Air Quality in the Guanzhong Basin, China. *Remote. Sens.* **2020**, *12*, 3042, doi:10.3390/rs12183042.
68. Filonchyk, M.; Yan, H.; Hurynovich, V.; Wang, Z. Impact of COVID-19 pandemic on air quality changes in Shanghai, China. *Environ. Forensics* **2021**, 1–6, doi:10.1080/15275922.2021.1892878.
69. Silver, B.; He, X.; Arnold, S.R.; Spracklen, D.V. The impact of COVID-19 control measures on air quality in China. *Environ. Res. Lett.* **2020**, *15*, 084021, doi:10.1088/1748-9326/aba3a2/meta.
70. E Marlier, M.; Xing, J.; Zhu, Y.; Wang, S. Impacts of COVID-19 response actions on air quality in China. *Environ. Res. Commun.* **2020**, *2*, 075003, doi:10.1088/2515-7620/aba425.
71. Xu, K.; Cui, K.; Young, L.-H.; Wang, Y.-F.; Hsieh, Y.-K.; Wan, S.; Zhang, J. Air Quality Index, Indicatory Air Pollutants and Impact of COVID-19 Event on the Air Quality near Central China. *Aerosol Air Qual. Res.* **2020**, *20*, 1204–1221, doi:10.4209/aaqr.2020.04.0139.
72. Tang, R.; Huang, X.; Zhou, D.; Wang, H.; Xu, J.; Ding, A. Global air quality change during the COVID-19 pandemic: Regionally different ozone pollution responses COVID-19. *Atmos. Ocean. Sci. Lett.* **2021**, *14*, 100015, doi:10.1016/j.aosl.2020.100015.
73. Su, Z.; Duan, Z.; Deng, B.; Liu, Y.; Chen, X. Impact of the COVID-19 Lockdown on Air Quality Trends in Guiyang, Southwestern China. *Atmosphere* **2021**, *12*, 422, doi:10.3390/atmos12040422.
74. Han, Y.; Lam, J.C.; Li, V.O.; Guo, P.; Zhang, Q.; Wang, A.; Crowcroft, J.; Gozes, I.; Fu, J.; Gilani, Z.; Wang, S. Outdoor Air Pollutant Concentration and COVID-19 Infection in Wuhan, China. *medRxiv* **2020**, https://doi.org/10.1101/2020.05.19.20106484.
75. Chen, J.; Hu, H.; Wang, F.; Zhang, M.; Zhou, T.; Yuan, S.; Bai, R.; Chen, N.; Xu, K.; Huang, H. Air quality characteristics in Wuhan (China) during the 2020 COVID-19 pandemic. *Environ. Res.* **2021**, *195*, 110879, doi:10.1016/j.envres.2021.110879.
76. Filonchyk, M.; Hurynovich, V.; Yan, H. Impact of Covid-19 lockdown on air quality in the Poland, Eastern Europe. *Environ. Res.* **2021**, *198*, 110454, doi:10.1016/j.envres.2020.110454.
77. Al-Qaness, M.A.; Fan, H.; Ewees, A.A.; Yousri, D.; Elaziz, M.A. Improved ANFIS model for forecasting Wuhan City Air Quality and analysis COVID-19 lockdown impacts on air quality. *Environ. Res.* **2021**, *194*, 110607, doi:10.1016/j.envres.2020.110607.
78. Bao, R.; Zhang, A. Does lockdown reduce air pollution? Evidence from 44 cities in northern China. *Sci. Total Environ.* **2020**, *731*, 139052, doi:10.1016/j.scitotenv.2020.139052.
79. Brimblecombe, P.; Lai, Y. Diurnal and weekly patterns of primary pollutants in Beijing under COVID-19 restrictions. *Faraday Discuss.* **2020**, *226*, 138–148, doi:10.1039/d0fd00082e.
80. Chang, Y.; Huang, R.; Ge, X.; Huang, X.; Hu, J.; Duan, Y.; Zou Z.; Liu, X.; Lehmann, M. Puzzling Haze Events in China During the Coronavirus (COVID-19) Shutdown. *Geophys. Res. Lett.* **2020**, *47*, 088533, doi:10.1029/2020gl088533.

81. Chen, Q.X.; Huang, C.L.; Yuan, Y.; Tan, H.P. Influence of COVID-19 event on air quality and their association in Mainland China. *Aerosol Air Qual. Res.* **2020**, *20*, 1541–1551.
82. Diamond, M.S.; Wood, R. Limited Regional Aerosol and Cloud Microphysical Changes Despite Unprecedented Decline in Nitrogen Oxide Pollution During the February 2020 COVID-19 Shutdown in China. *Geophys. Res. Lett.* **2020**, *47*, 088913, doi:10.1029/2020gl088913.
83. Chu, B.; Zhang, S.; Liu, J.; Ma, Q.; He, H. Significant concurrent decrease in PM2.5 and NO2 concentrations in China during COVID-19 epidemic. *J. Environ. Sci.* **2021**, *99*, 346–353, doi:10.1016/j.jes.2020.06.031.
84. Griffith, S.; Huang, W.; Lin, C.; Chen, Y.; Chang, K.; Lin, T.; Wang, S.; Lin, N. Long-range air pollution transport in East Asia during the first week of the COVID-19 lockdown in China. *Sci. Total Environ.* **2020**, *741*, 140214, doi:10.1016/j.scitotenv.2020.140214.
85. Ding, J.; van der A, R.J.; Eskes, H.J.; Mijling, B.; Stavrakou, T.; van Geffen, J.H.G.M.; Veefkind, J.P. NOx Emissions Reduction and Rebound in China Due to the COVID-19 Crisis. *Geophys. Res. Lett.* **2020**, *47*, 089912, doi:10.1029/2020gl089912.
86. Huang, L.; Liu, Z.; Li, H.; Wang, Y.; Li, Y.; Zhu, Y.; Ooi, M.; An, J.; Shang, Y.; Zhang, D.; Li, L. The Silver Lining of COVID-19: Estimation of Short-Term Health Impacts Due to Lockdown in the Yangtze River Delta Region, China. *GeoHealth* **2020**, *4*, 000272, doi:10.1029/2020gh000272.
87. Huang, Y.; Zhou, J.L.; Yu, Y.; Mok, W.-C.; Lee, C.; Yam, Y.-S. Uncertainty in the Impact of the COVID-19 Pandemic on Air Quality in Hong Kong, China. *Atmosphere* **2020**, *11*, 914, https://doi.org/10.3390/atmos11090914.
88. Le, T.; Wang, Y.; Liu, L.; Yang, J.; Yung, Y.L.; Li, G.; Seinfeld, J.H. Unexpected air pollution with marked emission reductions during the COVID-19 outbreak in China. *Science* **2020**, *369*, 702–706, doi:10.1126/science.abb7431.
89. Li, J.; Yang, H.; Zha, S.; Yu, N.; Liu, X.; Sun, R. Effects of COVID-19 Emergency Response Levels on Air Quality in the Guangdong-Hong Kong-Macao Greater Bay Area, China. *Aerosol Air Qual. Res.* **2021**, *21*, 200416, doi:10.4209/aaqr.2020.07.0416.
90. Li, L.; Li, Q.; Huang, L.; Wang, Q.; Zhu, A.; Xu, J.; Liu, Z.; Li, H.; Shi, L.; Li, R.; Chan, A. 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.* **2020**, *732*, 139282, doi:10.1016/j.scitotenv.2020.139282.
91. Li, Z.; Meng, J.; Zhou, L.; Zhou, R.; Fu, M.; Wang, Y.; Yi, Y.; Song, A.; Guo, Q.; Hou, Z.; et al. Impact of the COVID-19 Event on the Characteristics of Atmospheric Single Particle in the Northern China. *Aerosol Air Qual. Res.* **2020**, *20*, 1716–1726, doi:10.4209/aaqr.2020.06.0321.
92. Lian, X.; Huang, J.; Huang, R.-J.; Liu, C.; Wang, L.; Zhang, T. Impact of city lockdown on the air quality of COVID-19-hit of Wuhan city. *Sci. Total Environ.* **2020**, *742*, 140556, doi:10.1016/j.scitotenv.2020.140556.
93. Miyazaki, K.; Bowman, K.; Sekiya, T.; Jiang, Z.; Chen, X.; Eskes, H.; Ru, M.; Zhang, Y.; Shindell, D. Air quality response in China linked to the 2019 novel coronavirus (COVID-19) lockdown. *Geophys. Res. Lett.* **2020**, 47, e2020GL089252.
94. Kaewrat, J.; Janta, R. Effect of COVID-19 Prevention Measures on Air Quality in Thailand. *Aerosol Air Qual. Res.* **2021**, *21*, 200344, doi:10.4209/aaqr.2020.06.0344.
95. Stratoulias, D.; Nuthammachot, N. Air quality development during the COVID-19 pandemic over a medium-sized urban area in Thailand. *Sci. Total Environ.* **2020**, *746*, 141320, doi:10.1016/j.scitotenv.2020.141320.
96. Masum, M.H.; Pal, S.K. Statistical evaluation of selected air quality parameters influenced by COVID-19 lockdown. *Glob. J. Environ. Sci. Manag.* **2020**, *6*, 85–94, https://dx.doi.org/10.22034/GJESM.2019.06.SI.08.
97. Islam, S.; Tusher, T.R.; Roy, S.; Rahman, M. Impacts of nationwide lockdown due to COVID-19 outbreak on air quality in Bangladesh: A spatiotemporal analysis. *Air Qual. Atmos. Health* **2021**, *14*, 351–363, doi:10.1007/s11869-020-00940-5.
98. Roy, S.; Chowdhury, N.; Bhuyan. M.M.M. COVID-19 Induced Lockdown Consequences on Air Quality and Economy-A Case Study of Bangladesh. *J. Environ. Pollut. Hum. Health* **2020**, *8*, 55–68.
99. Kanniah, K.D.; Zaman, N.A.F.K.; Kaskaoutis, D.G.; Latif, M.T. COVID-19's impact on the atmospheric environment in the Southeast Asia region. *Sci. Total Environ.* **2020**, *736*, 139658, Erratum in **2020**, *745*, 142200, doi:10.1016/j.scitotenv.2020.139658.
100. Suhaimi, N.F.; Jalaludin, J.; Latif, M.T. Demystifying a Possible Relationship between COVID-19, Air Quality and Meteorological Factors: Evidence from Kuala Lumpur, Malaysia. *Aerosol Air Qual. Res.* **2020**, *20*, 1520–1529, doi:10.4209/aaqr.2020.05.0218.
101. Li, J.; Tartarini, F. Changes in Air Quality during the COVID-19 Lockdown in Singapore and associations with Human Mobility Trends. *Aerosol Air Qual. Res.* **2020**, *20*, 1748–1758, doi:10.4209/aaqr.2020.06.0303.
102. Seo, J.; Jeon, H.; Sung, U.; Sohn, J.-R. Impact of the COVID-19 Outbreak on Air Quality in Korea. *Atmosphere* **2020**, *11*, 1137, doi:10.3390/atmos11101137.
103. Han, B.-S.; Park, K.; Kwak, K.-H.; Park, S.-B.; Jin, H.-G.; Moon, S.; Kim, J.-W.; Baik, J.-J. Air quality change in Seoul, South Korea under COVID-19 social distancing: Focusing on PM2. 5. *Int. J. Environ. Res. Public Health* **2020**, *17*, 6208.
104. Ju, M.J.; Oh, J.; Choi, Y.-H. Changes in air pollution levels after COVID-19 outbreak in Korea. *Sci. Total Environ.* **2021**, *750*, 141521, doi:10.1016/j.scitotenv.2020.141521.
105. Agami, S. Impact of COVID-19 on Air Quality in Israel. *arXiv* **2020**, arXiv:2007.06501. Available online: https://arxiv.org/abs/2007.06501v1 (accessed on 14 April 2021).
106. Broomandi, P.; Karaca, F.; Nikfal, A.; Jahanbakhshi, A.; Tamjidi, M.; Kim, J.R. Impact of COVID-19 Event on the Air Quality in Iran. *Aerosol Air Qual. Res.* **2020**, *20*, 1793–1804, doi:10.4209/aaqr.2020.05.0205.
107. Mehmood, K.; Bao, Y.; Petropoulos, G.P.; Abbas, R.; Abrar, M.M.; Mustafa, A.; Soban, A.; Saud, S.; Ahmad, M.; Fahad, S. Investigating connections between COVID-19 pandemic, air pollution and community interventions for Pakistan employing geoinformation technologies. *Chemosphere* **2021**, *272*, 129809.

108. Bacak, T.; Dursun, Ş.; Toros, H. The Effect of COVID-19 Outbreak on Air Quality of Istanbul City Centre. 2020. Available online: https://www.researchgate.net/profile/Tugce-Bacak/publication/346059005_The_Effect_of_COVID-19_outbreak_on_Air_Quality_of_Istanbul_city_centre/links/5fb9307d458515b7975cc203/The-Effect-of-COVID-19-outbreak-on-Air-Quality-of-Istanbul-city-centre.pdf (accessed on 25 May 2021).
109. Şahin, A. The Effects of COVID-19 Measures on Air Pollutant Concentrations at Urban and Traffic Sites in Istanbul. *Aerosol Air Qual. Res.* **2020**, *20*, 1874–1885, doi:10.4209/aaqr.2020.05.0239.
110. Nguyen, T.P.M.; Bui, T.H.; Nguyen, M.K.; Nguyen, T.H.; Pham, H.L. Impact of Covid-19 partial lockdown on PM 2.5, SO 2, NO 2, O 3, and trace elements in PM 2.5 in Hanoi, Vietnam. *Environ. Sci. Pollut. Res.* **2021**, 1–11, doi:10.1007/s11356-021-13792-y.
111. Kerimray, A.; Baimatova, N.; Ibragimova, O.; Bukenov, B.; Kenessov, B.; Plotitsyn, P.; Karaca, F. Assessing air quality changes in large cities during COVID-19 lockdowns: The impacts of traffic-free urban conditions in Almaty, Kazakhstan. *Sci. Total Environ.* **2020**, *730*, 139179, doi:10.1016/j.scitotenv.2020.139179.
112. Anil, I.; Alagha, O. The impact of COVID-19 lockdown on the air quality of Eastern Province, Saudi Arabia. *Air Qual. Atmos. Health* **2021**, *14*, 117–128.
113. Faridi, S.; Yousefian, F.; Niazi, S.; Ghalhari, M.R.; Hassanvand, M.S.; Naddafi, K. Impact of SARS-CoV-2 on ambient air particulate matter in Tehran. *Aerosol Air Qual. Res.* **2020**, *20*, 1805–1811.
114. Anderson, B.; Dirks, K. A Preliminary Analysis of Changes in Outdoor Air Quality in the City of Southampton during the 2020 COVID-19 Outbreak to Date: A Response to DEFRA's Call for Evidence 1 on Estimation of Changes in Air Pollution Emissions, Concentrations and Exposure during the COVID-19 Outbreak in the UK. 2020. Available online: https://cfsotago.github.io/airQual/sccAirQualExplore_covidLockdown2020.html (accesssed on 12 May 2021).
115. Lee, J.D.; Drysdale, W.S.; Finch, D.P.; Wilde, S.E.; Palmer, P.I. UK surface NO2 levels dropped by 42 % during the COVID-19 lockdown: Impact on surface O3. *Atmos. Chem. Phys. Discuss.* **2020**, *20*, 15743–15759, doi:10.5194/acp-20-15743-2020.
116. Jephcote, C.; Hansell, A.L.; Adams, K.; Gulliver, J. Changes in air quality during COVID-19 'lockdown' in the United Kingdom. *Environ. Pollut.* **2021**, *272*, 116011, doi:10.1016/j.envpol.2020.116011.
117. Sannino, A.; D'Emilio, M.; Castellano, P.; Amoruso, S.; Boselli, A. Analysis of Air Quality during the COVID-19 Pandemic Lockdown in Naples (Italy). *Aerosol Air Qual. Res.* **2021**, *21*, 200381, doi:10.4209/aaqr.2020.07.0381.
118. Travaglio, M.; Yu, Y.; Popovic, R.; Selley, L.; Leal, N.S.; Martins, L.M. Links between air pollution and COVID-19 in England. *Environ. Pollut.* **2021**, *268*, 115859, doi:10.1016/j.envpol.2020.115859.
119. Ropkins, K.; Tate, J.E. Early observations on the impact of the COVID-19 lockdown on air quality trends across the UK. *Sci. Total Environ.* **2021**, *754*, 142374, doi:10.1016/j.scitotenv.2020.142374.
120. Wyche, K.; Nichols, M.; Parfitt, H.; Beckett, P.; Gregg, D.; Smallbone, K.; Monks, P. Changes in ambient air quality and atmospheric composition and reactivity in the South East of the UK as a result of the COVID-19 lockdown. *Sci. Total Environ.* **2021**, *755*, 142526, doi:10.1016/j.scitotenv.2020.142526.
121. Higham, J.; Ramírez, C.A.; Green, M.; Morse, A.P. UK COVID-19 lockdown: 100 days of air pollution reduction? *Air Qual. Atmos. Health* **2021**, *14*, 325–332, doi:10.1007/s11869-020-00937-0.
122. A Potts, D.; A Marais, E.; Boesch, H.; Pope, R.J.; Lee, J.; Drysdale, W.; Chipperfield, M.P.; Kerridge, B.; Siddans, R.; Moore, D.P.; et al. Diagnosing air quality changes in the UK during the COVID-19 lockdown using TROPOMI and GEOS-Chem. *Environ. Res. Lett.* **2021**, *16*, 054031, doi:10.1088/1748-9326/abde5d.
123. Briz-Redón, Á.; Belenguer-Sapiña, C.; Serrano-Aroca, Á. Changes in air pollution during COVID-19 lockdown in Spain: A multi-city study. *J. Environ. Sci.* **2021**, *101*, 16–26, doi:10.1016/j.jes.2020.07.029.
124. Mesas-Carrascosa, F.-J.; Porras, F.P.; Triviño-Tarradas, P.; García-Ferrer, A.; Meroño-Larriva, J. Effect of Lockdown Measures on Atmospheric Nitrogen Dioxide during SARS-CoV-2 in Spain. *Remote. Sens.* **2020**, *12*, 2210, doi:10.3390/rs12142210.
125. Donzelli, G.; Cioni, L.; Cancellieri, M.; Llopis-Morales, A.; Morales-Suárez-Varela, M. Relations between Air Quality and Covid-19 Lockdown Measures in Valencia, Spain. *Int. J. Environ. Res. Public Health* **2021**, *18*, 2296, doi:10.3390/ijerph18052296.
126. Petetin, H.; Bowdalo, D.; Soret, A.; Guevara, M.; Jorba, O.; Serradell, K.; García-Pando, C.P. Meteorology-normalized impact of the COVID-19 lockdown upon NO2 pollution in Spain. *Atmos. Chem. Phys. Discuss.* **2020**, *20*, 11119–11141, doi:10.5194/acp-20-11119-2020.
127. Baldasano, J.M. COVID-19 lockdown effects on air quality by NO2 in the cities of Barcelona and Madrid (Spain). *Sci. Total Environ.* **2020**, *741*, 140353, doi:10.1016/j.scitotenv.2020.140353.
128. Bassani, C.; Vichi, F.; Esposito, G.; Montagnoli, M.; Giusto, M.; Ianniello, A. Nitrogen dioxide reductions from satellite and surface observations during COVID-19 mitigation in Rome (Italy). *Environ. Sci. Pollut. Res.* **2021**, *28*, 22981–23004.
129. Coker, E.S.; Cavalli, L.; Fabrizi, E.; Guastella, G.; Lippo, E.; Parisi, M.L.; Pontarollo, N.; Rizzati, M.; Varacca, A.; Vergalli, S. The Effects of Air Pollution on COVID-19 Related Mortality in Northern Italy. *Environ. Resour. Econ.* **2020**, *76*, 611–634, doi:10.1007/s10640-020-00486-1.
130. Cameletti, M. The Effect of Corona Virus Lockdown on Air Pollution: Evidence from the City of Brescia in Lombardia Region (Italy). *Atmos. Environ.* **2020**, *239*, 117794, doi:10.1016/j.atmosenv.2020.117794.
131. Albrecht, L.; Czarnecki, P.; Sakelaris, B. Investigating the Relationship between Air Quality and COVID-19 Transmission. *J. data Sci. JDS* **2021**, *19*, 485–497, doi:10.6339/21-jds1010.
132. Granella, F.; Reis, L.A.; Bosetti, V.; Tavoni, M. COVID-19 lockdown only partially alleviates health impacts of air pollution in Northern Italy. *Environ. Res. Lett.* **2021**, *16*, 035012. Available online: https://iopscience.iop.org/article/10.1088/1748-9326/abd3d2/meta (accessed on 19 May 2021).

133. Dursun, S.; Sagdic, M.; Toros, H. The impact of COVID-19 measures on air quality in Turkey. *Environ. Forensics* **2021**, 22, 1–13, doi:10.1080/15275922.2021.1892876.
134. Aydın, S.; Nakiyingi, B.A.; Esmen, C.; Güneysu, S.; Ejjada, M. Environmental impact of coronavirus (COVID-19) from Turkish perceptive. *Environ. Dev. Sustain.* **2021**, *23*, 7573–7580, doi:10.1007/s10668-020-00933-5.
135. Kaskun, S. The effect of COVID-19 pandemic on air quality caused by tra c in Istanbul. *Res. Sq.* **2020**, 1–24, doi:10.21203/rs.3.rs-28880/v1.
136. Sbai, S.E.; Mejjad, N.; Norelyaqine, A.; Bentayeb, F. Air quality change during the COVID-19 pandemic lockdown over the Auvergne-Rhône-Alpes region, France. *Air Qual. Atmos. Health* **2021**, *14*, 617–628, doi:10.1007/s11869-020-00965-w.
137. Ginzburg, A.S.; Semenov, V.A.; Semutnikova, E.G.; Aleshina, M.A.; Zakharova, P.V.; Lezina, E.A. Impact of COVID-19 Lockdown on Air Quality in Moscow. *Dokl. Earth Sci.* **2020**, *495*, 862–866, doi:10.1134/s1028334x20110069.
138. Burns, J.; Hoffmann, S.; Kurz, C.; Laxy, M.; Polus, S.; Rehfuess, E. COVID-19 mitigation measures and nitrogen dioxide—A quasi-experimental study of air quality in Munich, Germany. *Atmos. Environ.* **2021**, *246*, 118089, doi:10.1016/j.atmosenv.2020.118089.
139. Dimovska, M.; Gjorgjev, D. The Effects of COVID-19 Lockdown on Air Quality in Macedonia. *Open Access Maced. J. Med Sci.* **2020**, *8*, 353–362, doi:10.3889/oamjms.2020.5455.
140. Gama, C.; Relvas, H.; Lopes, M.; Monteiro, A. The impact of COVID-19 on air quality levels in Portugal: A way to assess traffic contribution. *Environ. Res.* **2021**, *193*, 110515, doi:10.1016/j.envres.2020.110515.
141. Velders, G.J.; Willers, S.M.; Wesseling, J.; Elshout, S.V.D.; van der Swaluw, E.; Mooibroek, D.; van Ratingen, S. Improvements in air quality in the Netherlands during the corona lockdown based on observations and model simulations. *Atmos. Environ.* **2021**, *247*, 118158, doi:10.1016/j.atmosenv.2020.118158.
142. Dragic, N.; Bijelovic, S.; Jevtic, M.; Velicki, R.; Radic, I. Short-term health effects of air quality changes during the COVID-19 pandemic in the City of Novi Sad, the Republic of Serbia. *Int. J. Occup. Med. Environ. Health* **2021**, *34*, 1–15, doi:10.13075/ijomeh.1896.01784.
143. Bourdrel, T.; Annesi-Maesano, I.; Alahmad, B.; Maesano, C.N.; Bind, M.-A. The impact of outdoor air pollution on COVID-19: A review of evidence from in vitro, animal, and human studies. *Eur. Respir. Rev.* **2021**, *30*, 200242, doi:10.1183/16000617.0242-2020.
144. Menut, L.; Bessagnet, B.; Siour, G.; Mailler, S.; Pennel, R.; Cholakian, A. Impact of lockdown measures to combat Covid-19 on air quality over western Europe. *Sci. Total Environ.* **2020**, *741*, 140426, doi:10.1016/j.scitotenv.2020.140426.
145. Deroubaix, A.; Brasseur, G.; Gaubert, B.; Labuhn, I.; Menut, L.; Siour, G.; Tuccella, P. Response of surface ozone concentration to emission reduction and meteorology during the COVID-19 lockdown in Europe. *Authorea Preprints* **2020**, 28 https://doi.org/10.22541/au.160513378.82834373/v1.
146. Goldberg, D.L.; Anenberg, S.C.; Griffin, D.; McLinden, C.A.; Lu, Z.; Streets, D.G. Disentangling the Impact of the COVID-19 Lockdowns on Urban NO_2 From Natural Variability. *Geophys. Res. Lett.* **2020**, *47*, e2020gl089269, doi:10.1029/2020gl089269.
147. Pan, S.; Jung, J.; Li, Z.; Hou, X.; Roy, A.; Choi, Y.; Gao, H. Air Quality Implications of COVID-19 in California. *Sustainability* **2020**, *12*, 7067, doi:10.3390/su12177067.
148. Takagi, H.; Kuno, T.; Yokoyama, Y.; Ueyama, H.; Matsushiro, T.; Hari, Y.; Ando, T. Air Quality and COVID-19 Prevalence/Fatality. *medRxiv* **2020**, https://doi.org/10.1101/2020.06.14.20130740.
149. Berman, J.D.; Ebisu, K. Changes in U.S. air pollution during the COVID-19 pandemic. *Sci. Total Environ.* **2020**, *739*, 139864, doi:10.1016/j.scitotenv.2020.139864.
150. Jiang, Z.; Shi, H.; Zhao, B.; Gu, Y.; Zhu, Y.; Miyazaki, K.; Lu, X.; Zhang, Y.; Bowman, K.; Sekiya, T.; Liou, K. Modeling the Impact of COVID-19 on Air Quality in Southern California: Implications for Future Control Policies. *Atmos. Chem. Phys. Discuss.* **2020**, *21*, 8693–8708.
151. Zangari, S.; Hill, D.T.; Charette, A.T.; Mirowsky, J.E. Air quality changes in New York City during the COVID-19 pandemic. *Sci. Total Environ.* **2020**, *742*, 140496.
152. Liu, Q.; Harris, J.T.; Chiu, L.S.; Sun, D.; Houser, P.R.; Yu, M.; Duffy, D.Q.; Little, M.M.; Yang, C. Spatiotemporal impacts of COVID-19 on air pollution in California, USA. *Sci. Total Environ.* **2021**, *750*, 141592, doi:10.1016/j.scitotenv.2020.141592.
153. Adams, M.D. Air pollution in Ontario, Canada during the COVID-19 State of Emergency. *Sci. Total Environ.* **2020**, *742*, 140516, doi:10.1016/j.scitotenv.2020.140516.
154. Hernández-Paniagua, I.Y.; Valdez, S.I.; Almanza, V.; Rivera-Cárdenas, C.; Grutter, M.; Stremme, W.; García-Reynoso, A.; Ruiz-Suárez, L.G. Impact of the COVID-19 Lockdown on Air Quality and Resulting Public Health Benefits in the Mexico City Metropolitan Area. *Front. Public Health* **2021**, *9*, 642630, doi:10.3389/fpubh.2021.642630.
155. Zalakeviciute, R.; Vasquez, R.; Bayas, D.; Buenano, A.; Mejia, D.; Zegarra, R.; Diaz, V.; Lamb, B. Drastic Improvements in Air Quality in Ecuador during the COVID-19 Outbreak. *Aerosol Air Qual. Res.* **2020**, *20*, 1783–1792, doi:10.4209/aaqr.2020.05.0254.
156. Nakada, L.Y.K.; Urban, R.C. COVID-19 pandemic: Impacts on the air quality during the partial lockdown in São Paulo state, Brazil. *Sci. Total Environ.* **2020**, *730*, 139087, doi:10.1016/j.scitotenv.2020.139087.
157. Siciliano, B.; Carvalho, G.; da Silva, C.M.; Arbilla, G. The Impact of COVID-19 Partial Lockdown on Primary Pollutant Concentrations in the Atmosphere of Rio de Janeiro and São Paulo Megacities (Brazil). *Bull. Environ. Contam. Toxicol.* **2020**, *105*, 2–8, doi:10.1007/s00128-020-02907-9.
158. Zambrano-Monserrate, M.A.; Ruano, M.A. Has air quality improved in Ecuador during the COVID-19 pandemic? A parametric analysis. *Air Qual. Atmos. Health* **2020**, *13*, 929–938.

159. Cazorla, M.; Herrera, E.; Palomeque, E.; Saud, J. What the COVID-19 lockdown revealed about photochemistry and ozone production in Quito, Ecuador. *Atmos. Pollut. Res.* **2021**, *12*, 124–133, doi:10.1016/j.apr.2020.08.028.
160. Mendez-Espinosa, J.F.; Rojas, N.Y.; Vargas, J.; Pachón, J.E.; Belalcazar, L.C.; Ramírez, O. Air quality variations in Northern South America during the COVID-19 lockdown. *Sci. Total Environ.* **2020**, *749*, 141621, doi:10.1016/j.scitotenv.2020.141621.
161. Kutralam-Muniasamy, G.; Pérez-Guevara, F.; Roy, P.D.; Elizalde-Martínez, I.; Shruti, V. Impacts of the COVID-19 lockdown on air quality and its association with human mortality trends in megapolis Mexico City. *Air Qual. Atmos. Health* **2021**, *14*, 553–562, doi:10.1007/s11869-020-00960-1.
162. El-Magd, I.A.; Zanaty, N. Impacts of short-term lockdown during COVID-19 on air quality in Egypt. *Egypt. J. Remote. Sens. Space Sci.* **2020**, doi:10.1016/j.ejrs.2020.10.003.
163. Sekmoudi, I.; Khomsi, K.; Faieq, S.; Idrissi, L. Covid-19 lockdown improves air quality in Morocco. *arXiv* **2020**, arXiv:2007.05417. Available online: https://arxiv.org/abs/2007.05417v1 (accessed on 1 May 2021).
164. Khomsi, K.; Najmi, H.; Amghar, H.; Chelhaoui, Y.; Souhaili, Z. COVID-19 national lockdown in Morocco: Impacts on air quality and public health. *One Health* **2020**, *11*, 100200.
165. Meji, M.A.; Dennison, M.S.; Mobisha, M. Effect of COVID-19 Induced Lockdown on Air Quality in Kampala. *i-Manag. J. Future Eng. Technol.* **2020**, *16*, 43. Available online: https://www.researchgate.net/profile/Abisha-Meji-Milon/publication/346631417_EFFECT_OF_COVID-19_INDUCED_LOCKDOWN_ON_AIR_QUALITY_IN_KAMPALA/links/5fca620892851c00f84d55b9/EFFECT-OF-COVID-19-INDUCED-LOCKDOWN-ON-AIR-QUALITY-IN-KAMPALA.pdf (accessed on 19 May 2021).
166. Fuwape, I.A.; Okpalaonwuka, C.T.; Ogunjo, S.T. Impact of COVID -19 pandemic lockdown on distribution of inorganic pollutants in selected cities of Nigeria. *Air Qual. Atmos. Health* **2021**, *14*, 149–155, doi:10.1007/s11869-020-00921-8.
167. Wilson, A.D. Electronic-nose applications in forensic science and for analysis of volatile biomarkers in the human breath. *J. Forensic Sci. Criminol.* **2014**, *1*, 1–21.
168. Brooks, W.A.; Goswami, D.; Rahman, M.; Nahar, K.; Fry, A.M.; Balish, A.; Iftekharuddin, N.; Azim, T.; Xu, X.; Klimov, A.; Bresee, J.; Bridges, C.; Luby, S. Influenza is a major contributor to childhood pneumonia in a tropical developing country. *Pediatric Infect. Dis. J.* **2010**, *29*, 216–221.
169. Maji, K.J.; Dikshit, A.K.; Arora, M.; Deshpande, A. Estimating premature mortality attributable to PM2.5 exposure and benefit of air pollution control policies in China for 2020. *Sci. Total Environ.* **2018**, *612*, 683–693, doi:10.1016/j.scitotenv.2017.08.254.
170. Martelletti, L.; Martelletti, P. Air pollution and the novel Covid-19 disease: A putative disease risk factor. *SN Compr. Clin. Med.* **2020**, 15, 1–5. https://dx.doi.org/10.1007%2Fs42399-020-00274-4.
171. Ogen, Y. Assessing nitrogen dioxide (NO2) levels as a contributing factor to coronavirus (COVID-19) fatality. *Sci. Total Environ.* **2020**, *726*, 138605, doi:10.1016/j.scitotenv.2020.138605.
172. Zhu, L.; She, Z.-G.; Cheng, X.; Qin, J.-J.; Zhang, X.-J.; Cai, J.; Lei, F.; Wang, H.; Xie, J.; Wang, W.; et al. Association of Blood Glucose Control and Outcomes in Patients with COVID-19 and Pre-existing Type 2 Diabetes. *Cell Metab.* **2020**, *31*, 1068–1077.e3, doi:10.1016/j.cmet.2020.04.021.
173. Fattorini, D.; Regoli, F. Role of the chronic air pollution levels in the Covid-19 outbreak risk in Italy. *Environ. Pollut.* **2020**, *264*, 114732, doi:10.1016/j.envpol.2020.114732.
174. Huang, C.; Wang, Y.; Li, X.; Ren, L.; Zhao, J.; Hu, Y.; Zhang, L.; Fan, G.; Xu, J.; Gu, X.;…Cao, B. Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China. *Lancet* **2020**, *395*, 497–506.
175. Intergovernmental Panel on Climate Change (IPCC). *Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*; Metz, O.R.D.B.; Bosch, P.R.; Cambridge, L.A.M., Eds.; Cambridge University Press: Cambridge, UK, 2007.