

Investigation of Outdoor/Indoor Air Quality During the Outbreak of COVID-19: A Review Study

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ABSTRACT

The 2019 novel coronavirus (COVID-19) pandemic has enormously affected the world and become a worldwide problem. To control the spread of COVID-19, human behaviors are generally controlled in most countries. However, exposure to air pollution causes increased susceptibility to COVID-19. The goal of this review research was to investigate the outdoor/indoor air quality during the outbreak of COVID-19. A review search was carried out from the databases Scopus, PubMed, Web of Knowledge, and Embase using the key words: "air quality" and "COVID-19 pandemic". Twenty-four released articles were ultimately identified as eligible candidates for review study. The type of environment, country and city, type of study, goal of study, and study findings were analyzed. The results demonstrated the significant relationship between air pollution (PM_{2.5}, PM₁₀, SO₂, NO₂, CO, and O₃) and the COVID-19 event. Indoor pollutant concentrations were typically higher during COVID-19 lockdown. There is also a relationship between meteorological parameters (rainfall, relative humidity, temperature, wind speed, and sunlight) and COVID-19 spread. The air quality index (AQI) of most countries improved to varying grades of quality under the COVID-19 infection control. It is crucial that policy makers and decision makers adopt more valuable methods to assist betterment of air pollution, particularly in developing nations, or control contact with pollutants so as to preserve public wellbeing.

Keywords: air pollution, meteorological, COVID-19 infection, SARS-CoV-2, lockdown

INTRODUCTION

Coronavirus is one of the most important pathogens that affect a person's respiratory system. The Coronavirus infection 2019 (COVID-19) is caused by a new CoV-2, called severe acute respiratory syndrome coronavirus (SARS-CoV-2), which was previously identified as 2019 novel coronavirus (2019-nCoV) (Li et al., 2020). SARS-CoV-2 is spread from person to person through close communication, as well as via respiratory droplets greater than 5µm in diameter, which are produced when a sick person coughs, sneezes, speaks, or sings at close distances, typically less than 1-2m (Chirico et al., 2020). The airborne diffusion of droplet nuclei particles smaller than 5µm in diameter is considered as an important cause of infection (Correia et al., 2020; Sadeghi et al., 2020). Transmission dynamics of COVID-19 is governed by several systemic causes, including normal factors (i.e., biological specifications of virus, latency time, etc.), particular factors (e.g., complex interaction between air quality, climatic conditions, and biological specifications of viral infection), and wellbeing level of individuals (lifestyle, immune system, age, gender, etc.) (Ahmadi and Fadaei 2021; Coccia, 2020). There is an

inextricable connection between meteorological variables and air pollutants (Hou and Xu, 2022). Major air pollutants include particulate matter with diameters less than or equal to 10µm (PM₁₀); or 2.5µm or less (PM_{2.5}), nitrogen dioxide (NO₂), carbon monoxide (CO), black carbon (BC), sulfur dioxide (SO₂), volatile organic compounds (VOCs), ozone (O₃). Aerosol optical depth (AOD) levels and meteorological factors (wind rate, wind direction, temperature, relative humidity, and sunlight under the movement control order [MCO]) are among meteorological variables (Coccia, 2021; Rosario et al., 2020) affecting air quality. The air quality condition is explained on the basis of the pollutant standard index (PSI), air quality index (AQI), air quality health index (AQHI), and air pollutant index (API) of 5 or 6 key parameters. Additionally, CO₂ is generally recommended as the key indoor pollutant indicator and the index of the forcefulness of ventilation and the regeneration capability of the indoor environment (Fernández-Agüera et al., 2019). Every specification of the socio-economic and health effects of COVID-19 must be understood to control it. Many researchers have demonstrated that the prevalence of these infections can also be due to long-term exposure to atmospheric pollution, particularly nitrogen dioxide (NO₂), and particle matter with diameters of 2.5µm

(PM_{2.5}) entering the air because of human-made actions (mostly fossil fuel burning from motor vehicles, traffic, transport and the combustion of fuels for industrial facilities, commercial and household appliances and power stations) and natural processes (lightning, crystal dust, dust storms, and soil reactions). High exposure to pollutants is associated with hypertension, heart and cardiovascular diseases, asthma, bronchiolitis and also lung cancer, central nervous system functional disorders, cutaneous diseases, elevated rate of hospitalization, chronic obstructive pulmonary disease (COPD), considerable deficiencies in growth of lung function in children, poor lung role in adolescents or lung damage, and diabetes (Farhadi et al., 2020; Gan et al., 2012; Ogen, 2020; Shin et al., 2020). Additionally, air pollution may affect mental health, conception, fertility, and defensive cost (He et al., 2020; Ito and Zhang, 2020). Air pollution also imposes economic burden on public and healthcare providers (Farhadi et al., 2020). There are a few research studies on indoor air pollution during the outbreak of COVID-19. Therefore, this event has caused most nations to announce stay-at-home orders as a protective measure to be taken to prevent the release of the virus. Therefore, the main human-made resources of emissions in urban regions, particularly in the transport sector, have considerably decreased with these quarantine periods (Dong et al., 2019; Navinya et al., 2020). In this research, the levels of six main air pollutants (PM₁₀, PM_{2.5}, SO₂, NO₂, O₃, and CO), which have been evaluated in eight countries worldwide under COVID-19, are investigated. This fast literature review tries to provide adequate knowledge and strategies for improving outdoor and indoor air quality during a pandemic or crisis. Thus, in this study, the researcher evaluated the outdoor/indoor air quality during the outbreak of COVID-19.

METHODS

In the present study, a multidisciplinary reviewing framework was used to search articles on air pollution. To achieve this goal, the databases were systematically searched using various combinations of the following 34 keywords: “air-pollution OR air quality”, “air-pollution AND COVID-19”, “COVID-19 AND indoor pollution”, “indoor air quality AND COVID-19”, “Movement control order AND air pollution”, “Movement control order AND COVID-19”, “Change of air quality AND COVID-19”, “outdoor air quality AND COVID-19”, “PM_{2.5} AND COVID-19 infection”, “Covid-19 Lockdown AND Air Quality Index”, and “Covid-19 Lockdown AND climate parameters”. Articles on COVID-19 lockdown and the air pollution-related indicators were reviewed. Moreover, references of the identified articles were also reviewed to increase the comprehensiveness of the search. After all entitlements/abstracts were separately reviewed to recognize the possible related articles, the author selected research studies for full article review.

The identified articles were found eligible after evaluating against inclusion criteria, objectives, and recommended indicators. The inclusion criteria were: access to the original article, English language, and investigating the outdoor/indoor air quality during the outbreak of the COVID-

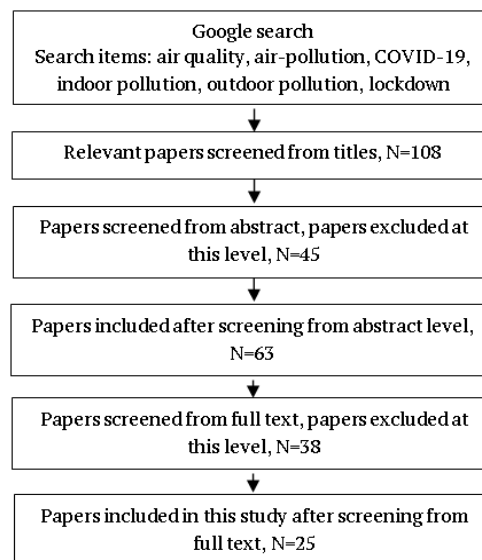


Figure 1. Chart< presentation of the review process

19 pandemic. The exclusion criteria were no access to the full-text article, review studies, book reviews, guidelines, protocols, letters-to-editors, articles submitted to conferences, theses, white papers, etc. As shown in **Figure 1**, 108 peer reviewed publications were accessed based on the relevance of titles to the research. These articles were further screened to 63 after reading through their abstracts. Following full text screening of the articles, 25 of them were used for this review, excluding the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) reference (Moher et al., 2010). Data related to the name of author(s), country of implementation, objectives, study findings, type of environment, and main variables/parameters, such as PM₁₀, PM_{2.5}, CO, NO₂, SO₂, VOC_s, O₃, AOD, and AQI and outcomes were collected. The method used for review was based on (1) outdoor air pollutants during COVID-19 pandemic, (2) effects of meteorological items and COVID-19 outbreak, and (3) indoor air pollutants under COVID-19 outbreak.

FINDINGS

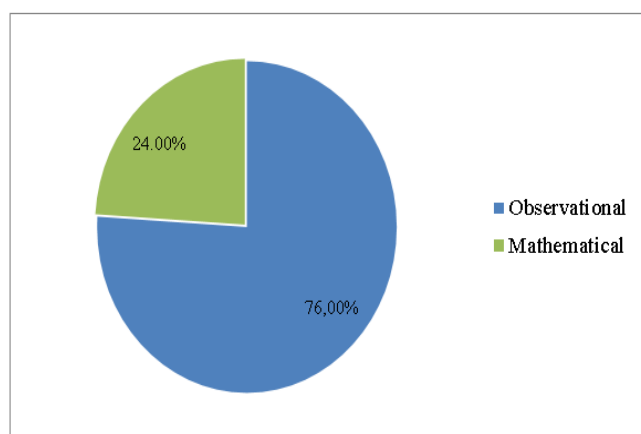
The main results are provided in **Table 1**. Of all identified studies, 17 were observational research on air pollution and COVID-19 pandemic during lockdown. These articles were from China (9), the USA (1), Spain (2), Italy (3), India (3), Malaysia (4), Singapore (1), and Brazil (2). Out of 25 articles studied in this systematic review, 6 (24%) and 19 (76%) studies were mathematical and observational, respectively (**Figure 2**). Twenty-two, 1, and 3 studies were concerned with the association between the outdoor and indoor air pollution and COVID-19, and meteorological parameters and COVID-19, respectively. This research found that the mean level of PM₁₀, PM_{2.5}, CO, NO₂, SO₂, and VOC_s reduced and air quality index improved in about 68% of reported research studies, and only in 20% of research studies, O₃ concentrations increased during COVID-19 pandemic. In the discussion section, the most important findings are discussed in three parts, including the outdoor air pollutants during the COVID-19 outbreak, effects of meteorological items and COVID-19 outbreak, and indoor air pollutants during the COVID-19 outbreak.

Table 1. Most important specifications of reviewed articles

Type of environment	Country	Type of study	Goal of study	Findings & recommendations	References
Indoor	Spain (Madrid)	Observational	Survey of air quality in residences in Madrid before & during outbreak of COVID-19 pandemic	Daily mean concentration of PM _{2.5} , NO ₂ , & VOC _s increased by 12%, 37%, & 559%, respectively under COVID-19 pandemic	Domínguez-Amarillo et al. (2020)
Outdoor	USA	Observational	Survey of air quality & COVID-19 mortality in USA	A statistically considerable increase in PM _{2.5} may increase susceptibility of infection & mortality from COVID-19	Wu et al. (2020b)
Outdoor	Italy	Observational	Relationship between air quality & wind speed	High wind speed has lower numbers of COVID-19 cases	Coccia (2021)
Outdoor	Italy	Observational	Association between factors (air pollution, climatic, & biological characteristics of virus) & COVID-19 transmission	Mechanisms of COVID-19 outbreak: air pollution- to-person transmission & person-to-person transmission	Coccia (2020)
Outdoor	Brazil	Observational	Association between weather factors (temperature, humidity, sunlight, wind speed, & precipitation) & COVID-19	Climatic factors like humidity, temperature, solar irradiation, & wind speed have negative correlation with COVID-19	Rosario et al. (2020)
Outdoor	China	Mathematical	Air pollution in China during outbreak of COVID-19 pandemic	Major air pollutants that were considerably reduced include: AQI by 20.56, PM _{2.5} by 19.01%, PM ₁₀ by 20.20%, & NO ₂ by 2.13%	Song et al. (2021)
Outdoor	China (Beijing-Tianjin Hebei)	Mathematical	Effects of COVID-19 quarantine on air quality	Quarantine had a considerable affirmative impact on air quality: AQI (15.2%), NO ₂ (37.8%), PM ₁₀ (33.6%), PM _{2.5} (21.5%), & CO (20.4%)	Wang et al. (2021)
Outdoor	China	Mathematical	Effects of COVID-19 quarantine on air quality	The quarantine measures decreased AQI by 19.84 & PM _{2.5} by 14.07%	He et al. (2020)
Outdoor	China	Mathematical	Does lockdown decrease air pollution?	Significantly reduced factors include AQI (7.80%), SO ₂ (6.76%), PM _{2.5} : (5.93%), PM ₁₀ (13.66%), NO ₂ (24.67%), & CO (4.58%)	Bao and Zhang (2020)
Outdoor	India	Mathematical	Evaluation of ecological effect of quarantine	Reduction of 85.1% in PM _{2.5} , PM ₁₀ , & NO ₂ ; CO has also reduced significantly, which is finding of constrained personal actions	Lokhandwala and Gautam (2020)
Outdoor	Spain (Barcelona)	Observational	Revolutions in air quality during outbreak of COVID-19 pandemic	Black carbon & NO ₂ concentrations decreased by 50% during quarantine phase; PM ₁₀ reduced but at a much lesser level, reducing agents are still unrevealed; O ₃ levels raised by about 50%.	Tobías et al. (2020)
Outdoor	Brazil (Rio de Janeiro)	Observational	Effect of COVID-19 quarantine on air quality	PM ₁₀ , NO ₂ , & CO levels decreased & O ₃ levels increased during COVID-19 pandemic	Dantas et al. (2020)
Outdoor	Malaysia (Klang Valley)	Mathematical	Air pollutants during COVID-19 pandemic	NO, NO ₂ , & CO reduced by 77.30%, 55.30%, & 64.80%, respectively; O ₃ levels increased by around 30% during COVID-19 quarantine phase	Latif et al. (2021)
Outdoor	India (Delhi)	Observational	Effect of COVID-19 quarantine phase on air pollution	NO ₂ , PM _{2.5} , PM ₁₀ , & CO reduced by 52.68%, 50.00%, 50.00%, & 30.35%, respectively; air quality have improved around 60% during COVID-19 phase	Mahato et al. (2020)
Outdoor	Malaysia	Observational	Effect of COVID-19 on atmospheric environment	Parameters of air pollution levels decline during COVID-19 quarantine phase ranged from 26-31%, 23-32%, 63-64%, 9-20%, & 25-31% in PM ₁₀ , PM _{2.5} , NO ₂ , SO ₂ , & CO, respectively	Kanniah et al. (2020)
Outdoor	China (Wuhan)	Observational	Effect of COVID-19 quarantine on air pollution & health	Two parameters PM _{2.5} & NO ₂ levels reduced by 35% and 63%, respectively during lockdown period	Cole et al. (2020)
Outdoor	Malaysia	Observational	To evaluate changes of four main air quality concentrations during COVID-19 quarantine phase	Mean levels of factors CO, PM _{2.5} , & NO ₂ reduced by 21.74%, 23.1%, & 54.0%, respectively, whilst that of SO ₂ was invariable	Ash'aari et al. (2020)
Outdoor	China (East China)	Observational	Assessing COVID-19 impact on changes of air pollution	Values of CO & NO ₂ reduced by 20% & 30% & this led to better air quality in short period during COVID-19 quarantine	Filonchik and Peterson (2020)

Table 1 (Continued). Most important specifications of reviewed articles

Type of environment	Country	Type of study	Goal of study	Findings & recommendations	References
Outdoor	Singapore	Observational	Variations in air pollution under COVID-19 pandemic	Values of factors PM ₁₀ , PM _{2.5} , NO ₂ , CO, SO ₂ , & PSI reduced by 23%, 29%, 54%, 6%, 52%, & 19% respectively, while that of O ₃ increased by 18%	Li and Tartarini (2020)
Outdoor	Malaysia	Observational	Air quality during stay-at-home order	PM _{2.5} levels reduced by 58.4% under movement control order (MCO); decline did not only depend on lockdown	Abdullah et al. (2020)
Outdoor	Italy (Milan)	Observational	Effect of COVID-19 quarantine phase on air quality pollution	A considerable decline was found in concentrations of PM ₁₀ , PM _{2.5} , black carbon, CO, benzene, & NO _x during lockdown	Collivignarelli et al. (2020)
Outdoor	India	Observational	Effects of COVID-19 quarantine on air quality	Air pollutants, including PM ₁₀ , PM _{2.5} , NO ₂ , & CO decreased during COVID-19 lockdown by 71%, 68%, 63%, & 87%, respectively	Navinya et al. (2020)
Outdoor	China (Mainland)	Observational	Effect of COVID-19 on air quality	Average levels of parameters PM _{2.5} , PM ₁₀ , SO ₂ , NO ₂ , & CO reduced by 14%, 15%, 12%, 16%, & 12%, respectively whilst level of O ₃ raised by 9%	Chen et al. (2020)
Outdoor	China (Wuhan)	Mathematical	Relationships between climatic items (temperature & humidity) & death COVID-19 cases	Influence of meteorological (temperature change & moisture) items on COVID-19 fatality	Ma et al. (2020)
Outdoor	China (122 cities)	Observational	Association between environment temperature & COVID-19 infection	There is a relationship between temperature & counts of COVID-19	Xie and Zhu (2020)

**Figure 2.** Specification type of design articles

DISCUSSION

Outdoor Air Pollutants During the COVID-19 Outbreak

In this study, a comprehensive literature review was conducted concerning the correlation between air pollution and COVID-19 crisis. In total, 25 articles were found to be eligible for a full evaluation. 17 articles were observational and investigated the association between air quality (i.e. effectiveness and key elements) and COVID-19 pandemic. According to the results (Table 1), the emission levels of the pollutants PM_{2.5}, PM₁₀, and NO₂ reduced, whilst the emitted levels of SO₂, CO, and O₃ did not decline considerably in the short period. More analysis demonstrated that there was no electricity generation and supply industry turn off, and the corresponding development of the burning and heating period of household stoves may be the cause why the levels of SO₂ and CO did not vary considerably. Moreover, the level of O₃ is related to solar irradiation and the levels of NO_x, which may indicate the absence of important variations in O₃ levels in a short time. The O₃, a secondary pollutant, is produced when

oxygen in the air is exposed to sunlight and combines with NO_x and volatile organic compounds in the air. It takes some time for the level of O₃ to change, so no change in O₃ was captured in the short term (Song et al., 2021).

Another study by Tobías et al. (2020) reported that the O₃ levels noticeably raised in the town as an outcome of three agents, including first, the reduction of NO_x in a VOC-restricted environment that causes the O₃ level in town to raise; second, the reduction of NO that decreases consumption of O₃ and causes an increase in the O₃ levels; and third, the usual increase of the exposure to the sun's rays and temperature during many seasons of the year. Briz-Redón et al. (2021) stated that there is a considerable association between air quality and the incidence of the COVID-19. Short time contact to greater levels of five parameters PM₁₀, PM_{2.5}, CO, O₃, and NO₂ is linked to a raised chance of getting sick from COVID-19.

Another study by Brandt et al. (2020) reported that a positive relationship was observed between outcome pollution measures from the air pollution index (CO, NO₂, SO₂, O₃, and PM₁₀) and COVID-19 case-mortality rates. Conticini et al. (2020) illustrated the possible association between pollution and the development of acute respiratory distress syndrome (ARDS), and eventually, death.

Tian et al. (2021) demonstrated that the AQI of most cities improved to varying grades of quality during the COVID-19 pandemic; the city crowding levels altered post COVID-19 pandemic; and carbon dioxide releases from municipal vehicles in Canada have consecutively reduced. These were principally associated with a reduction in economic development and transportation limitations that cause a modification in energy use and a decrease in emissions (Filonchik and Peterson, 2020). Another research by Dang and Trinh (2021) explained that the levels of PM_{2.5} and NO₂ reduced by 4% and 5% on a universal level, respectively. They also found that reducing individual movements can help improve air quality. Cameletti (2020) reported that the MCO in the city

of Brescia in Italy has definitely lowered the rate of road travel, thus reducing the most important emitted source related to NO₂ and PM₁₀ levels. According to the results, the reduction of air pollution and improvement of air quality may possibly decrease the mortality rate of COVID-19 and attenuate the spread of the infection (Fattorini & Regoli, 2020; Wu et al., 2020b). Besides, there are several research studies that illustrate towns with higher outdoor air pollutants, such as NO₂ level in Italy, Spain, France, and Germany (Ogen, 2020), PM_{2.5} level in USA (Wu et al., 2020a), and PM₁₀ level in Kuwait (Achilleos et al., 2019), have had an upper mortality rate when affected by COVID-19. One study revealed a robust relationship between the level of NO₂ and fatality of COVID-19 (Ogen, 2020).

Another research by Briz-Redon et al. (2021) stated that the major and minor COVID-19 quarantines were not long sufficient to considerably improve the air quality regarding all the measured pollutants like PM₁₀, O₃, CO, SO₂, and NO₂. Changes in air quality may be indirectly related to the quarantine due to various factors, such as the meteorological and their zonal or long-distance transport that are involved in the causes of these changes. In a study by Filonchik and Peterson (2020), the diurnal levels of PM_{2.5}, PM₁₀, SO₂, NO₂, and CO were reported to decrease by 9%, 77%, 31.3%, 60.4%, and 3%, respectively, during the COVID-19 quarantine phase. The reason for reduction of PM and NO₂ may be due to the reduced transport activities; whereas the reduction of SO₂ and CO levels may be due to stationary sources. Another study by Wetchayont (2021) explained that PM_{2.5}, PM₁₀, and O₃ reduced by 15.8%, 31.7%, and 7.1%, respectively during the quarantine phase. One study illustrated that concentrations of PM_{2.5} and NO₂ reduced by 36% and 51%, respectively, during the lockdown time (Zangari et al. 2020).

Effects of Meteorological Items and COVID-19 Outbreak

Recent research studies have shown the association between COVID-19 spread and temperature and humidity (Ma et al., 2020; Xie and Zhu, 2020). However, the possible effect of PM_{2.5} on COVID-19 is vague and it might be significant for decision makers and policy makers to take suitable measures to limit the increase of the COVID-19 transmission caused by aerosol diffusion (Chen et al., 2020). The climate is the most important parameter in determining the outbreak rate of COVID-19, for example, the mean temperature was considerably associated with COVID-19 (Tosepu et al., 2020). In a study, Elsaid and Ahmed (2021) noted that the increased temperature, wind speed, and overall increase in sunlight have been shown to be potential climatic parameters that gradually reduce the effects of the epidemic in Rio de Janeiro. One study reported that temperature (mean and minimum) and air quality were considerably related with the COVID-19 outbreak (Bashir et al., 2020). Another study by Dabisch et al. (2021) illustrated that an increase in temperature raises the decomposition rate of the contagious SARS-CoV-2 in aerosols. A study reported that the rate of virus inactivation in aerosol particles and droplets rises at middle relative humidity (RH), e.g., 40–60%, as compared to other moisture levels (Lin and Marr, 2019). Some studies say that COVID-19 deactivation is best at around 50–80°C and 40–50% relative humidity (Rezaei et al., 2020). Latif et al. (2021) demonstrated that the effect of

rainfall, relative humidity, temperature, and sunlight can be regarded as minimal under the COVID-19 lockdown compared to the same parameters recorded in the previous years. Besides, meteorological factors affect the occurrence and intensity of SARS-COV-2 disease (Cacho et al., 2020). Moreover, in polluted cities with low wind speed, the accelerated transmission of viral infection is due to air pollution-to-person transmission rather than person-to-person transmission (Coccia, 2020).

One study reported that the mean value of O₃ and NO₂ showed raised levels in winter and low levels in summer (Hoque et al., 2020). Further pressures appear to have a positive impact on the type of pollution. Particulate matter cannot diffuse suitably and tends to accumulate, leading to high loads of atmospheric particles (Czerwińska and Wielgosiński, 2020). Briz-Redón et al. (2021) found no evidence related to the decrease in COVID-19 incidences at warmer average, lowest and highest temperatures. However, non-climatic factors like the density of population, people by age, quantity of passengers and number of firms were taken into account in the analysis, and the obtained results need to be interpreted cautiously (Briz-Redón and Serrano-Aroca, 2020). In sum, it is impossible that air temperature and optimal RH combinations for virus inactivation be far from those typical for human comfort. Another study showed that the air temperature and wind direction are related to a considerable reduction in the level of PM₁₀ and PM_{2.5}. On the contrary, relative air humidity was most strongly negatively correlated with the concentration of particulate matter (Radzka, 2020). Under a high-speed wind situation, respiratory droplets may convert to very small respiratory droplets in the wind direction. In this situation, the risk of SARS-CoV-2 transmission increases (Nazari et al., 2021). One study stated that the humidity, wind speed, and sunlight have an indirect relationship with the outbreak rate (Ahmadi et al., 2020). Therefore, the influence of meteorological conditions cannot be ignored and further research must be conducted in the future.

Indoor Air Pollutants During the COVID-19 Pandemic

One of the major origins of particulate matter in dwelling houses is the kitchen as a food preparation area emitting steam, smoke, and aerosols (Tan et al., 2013). Due to the possibility of gas-reentrance via the infiltration air flow, smoke and effluents can be released indoor through indirect paths if there is a lack of a suitable extraction system space. Another huge contributor, which is on rise in houses now, is the application of cleaning products and disinfectants (Quang et al., 2013), as well as cosmetic and individual health factors (fresheners, hair sprays, etc.) (Sangiorgi et al., 2013). Before COVID-19, people spent less than 60% of their diurnal time indoors, while they now are staying at home 100% of the time on a prolonged basis (Domínguez-Amarillo et al., 2020). Although the city's outdoor air pollution was reduced during quarantine, the public's contact with indoor pollutants (e.g. PM_{2.5}, VOCs, CO₂, and NO₂, etc.) was commonly further transitory and continuous. There are many research studies relevant to indoor air pollution and COVID-19 (Domínguez-Amarillo et al., 2020; Nwanaji-Enwerem et al., 2020). One

study reported that the CO₂ level did not exceed 1000 mg/l in indoor air buildings (Ahlawat et al., 2020).

Indoor air quality means the air purity in and around buildings and facilities is specifically in relation to the health and comfort of building residents. Inadequate ventilation can lead to a rise in the levels of pollutants carrying the coronavirus in restricted places by not feeding enough outside air to further attenuate these pollutants and not removing the indoor air pollutants outside the ventilated region. Temperature and humidity are among the parameters affecting the reduction or increase of the spread of the coronavirus (Elsaid and Ahmed, 2021). Research on the indoor air quality in houses under COVID-19 quarantine is also restricted and most research addresses the home sanitizer agents as specifically related to the origin of indoor pollution. Indoor environment vulnerabilities, including domestic comfort and work accomplishment-indoor air quality (IAQ) are often perceived as more acceptable at low RH and low temperature, depending on changes not only of the VOC emission profile, but also of the dynamics, composition, deposition and re-suspension of inhaled (Spena et al., 2020). The meteorological situation may also play an important role in air pollution-virus interactions. Although, a recent study did not find any evidence of an association between solar UV radiation and COVID-19, air pollution, particularly PM, can reduce UV penetration, as illustrated by various research studies, which explained that air pollutants, such as PM considerably reduced vitamin D synthesis (Bourdrel et al., 2021). Current research explains that microbial community composition and level are considerably affected by particle concentration and dimension (Comunian et al. 2020).

Moreover, the level and infectivity of smaller airborne particles reduce more slowly, and thus their longer residence time in the air emphasizes the concern that they pose. Both are applicable to SARS-CoV-2, which has a size in the order of 20nm (Spena et al., 2020). Current research in the United States and Italy has reported that COVID-19 can remain in aerosols for more than 3 h and diffuse in long distances through the particles in the air (Jia et al., 2021).

CONCLUSIONS

The results of this review study revealed the significance of the relationship between air pollutants PM_{2.5}, PM₁₀, SO₂, NO₂, CO, and O₃, and COVID-19 phenomenon. Twenty-four precise evaluations indicated that the AQI in most countries improved to varying grades during the COVID-19 pandemic. Indoor pollutant concentrations were normally higher than outdoor pollutant concentrations during the COVID-19 lockdown. There is a relationship between meteorological items (rainfall, RH, temperature, wind direction, wind speed, and sunlight) and the COVID-19 spread. The effects of temperature and RH on COVID-19 spread are of great interest among meteorological factors. According to the findings of this study, if confirmed by future studies, air quality should also be considered as part of an integrated approach toward sustainable development, human health protection, and prevention of epidemic spreads. Considering the potential transmission paths of COVID-19, social and physical

distancing, personal protective equipment, and environmental disinfection are currently effective ways to slow down the transmission of COVID-19, and environmental pollution control can enhance people's overall capability to oppose respiratory infections.

There is a tight linkage between economics and environmental pollution. The reeducation of economic action and traffic limitations openly affected the modification of energy consumption in countries and effectively decreased environmental pollution. Based on the WHO, about 90% of the world's population are exposed to air pollution levels, which put them at increased risks for serious cardiorespiratory diseases, including cancer. Most studies demonstrate that both long-term and short-term exposures to high concentrations of pollutants are associated with an increase in COVID-19 transmission globally. It is crucial that policy makers and decision makers adopt more valuable methods to assist betterment of air pollution, particularly in developing nations, or control contact with pollutants so as to preserve public wellbeing. Seven recommendations for air quality improvement are as follows:

1. The scientists are suggested to conduct further research considering the association between the indoor air quality and COVID-19 outbreak in the future.
2. Further research is required to acquire comprehensive awareness of aerosol diffusion of COVID-19 so that more validated and useful procedures can be used to prevent the pandemic.
3. It should be stated that other factors, e.g., climate conditions, vehicles congestion, industrial actions, and fuel combustion must be well thought out.
4. The inactivation time of coronavirus in the air under various environmental conditions, such as temperature, RH, solar radiation, wind speed, etc., as well as the inactivation time of coronavirus on various types of surfaces should be fully investigated.
5. Air quality should be considered as a component of an integrated method that is helpful for sustainable development, human health protection, and control of pandemics.
6. The CO₂ monitors should be used in indoor buildings like health care centers, hospitals, nursing homes, schools, restaurants, dormitories, and universities.
7. Methods to decrease air pollution at the origin must be established and should be used in all industries and power plants.

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