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Effect of COVID-19 on air quality and pollution in different countries

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ABSTRACT

Introduction: COVID-19 is a pandemic that affected humans’ lives and activities through the year 2020 in a way that was not witnessed in recent years. Many governments declared a complete lockdown as a try to stop the transmission of the disease. This lockdown resulted in a good recovery in environmental health, where air pollutants levels dramatically decreased.

Theory: There are two relations between air pollution and COVID-19, one is before the disease spread, and the other is after. Before the disease spread, many areas had high levels of contaminants in the air due to industrial activities, transportation, and human density. These areas had the highest infection rates and death cases. This could be attributed to two reasons, the aerosol could help to spread the virus at a higher rate, and air pollutants could negatively affect peoples’ lungs, which assisted the virus in attacking the patients brutally.

Results: After the disease spread, the lockdown that was applied in the major industrial countries led to a decrease in the pollutants levels and an increase in the ozone level in the air. This lockdown improved the air quality worldwide to a level that all political conferences and agreements could not reach. In this review, we are showing the impact of COVID-19 on air pollutants in different countries.

Summary: This paper provides information about pollutants’ influence on human and environmental health that other researchers obtained in different areas of the globe before and after the pandemic. This could give ideas about the impact of humans on the environment and the possible ways of recovering the environment’s health.

1. Introduction

COVID-19 has spread in more than 200 countries worldwide, where many governments declared full or partial lockdown for different periods. For instance, India had a three-week full closure started from March 24th, 2020, in an attempt to stop the virus from spreading. This lockdown resulted in activities suspension of industrial factories and transportation facilities, especially in large cities

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as Delhi. As much as the air pollution was high, the air recovery ratio after the lockdown was high too (Kotnala et al., 2020). The environment has no direct evidence of spreading or preventing SARS-CoV-2; though, polluted air could cause consequences to humans’ lungs, which increase the rate of getting a viral infection (Yousif, 2020). Also, the environment surrounds us anyhow, so it could transfer, stop, and keep the etiological causes.

On the other hand, clean surrounding is anticipated to decrease the severity of viral infections and maintain the lungs healthy (Alsayed et al., 2020). Furthermore, the type of consumed food could affect the infection and mortality rates, where the quality of food is related to its original environment (Aldoori et al., 2021). Rajagopaian et al. (2020) studied the importance of wearing masks in order to prevent COVID-19 transmission by comparing the air pollutant sizes with the virus. Though wearing masks could not afford enough protection, washing hands and maintaining social distance are inevitable (Hadi et al., 2020a). Since simple masks could prevent aerosols of the size of 10 μm, it was suggested that they could flatten the infection curve of COVID-19.

Other studies suggested that there is a direct link between air pollution and disease spreading, where it was found that the level of particulate matter of the size 2.5 μm (PM$_{2.5}$) has affected the influenza infection rate in Beijing. At the same time, the O$_3$ and CO levels influenced influenza spreading in negative and positive ways, respectively. Small particles, such as PM$_{2.5}$, could suspend in the air for a while and increase the hazard of inhaling viruses and causing chronic respiratory problems (Ali et al., 2019). This could explain the mortality rates in Baghdad, where Aldoura had the highest death cases from coronavirus in Baghdad. Aldora has one of the largest refineries in Iraq and one of the main power stations in Baghdad, in addition to many infrastructure services and small companies (Al-Suhaili and Al-Khafaji, 2009). These facilities discard different types of pollutants with different sizes and toxicity levels. Similarly, it was reported that large cities in China and Italy had the highest COVID-19 infection cases (Frontera et al., 2020).

On the other hand, it was noticed that the mortality rate of COVID-19 is related to two factors, health problems and age, where three fourth of dead people had chronic diseases and aged higher than 80 years. With this, based on a report in March-2020 by Isaifan (2020), surprisingly, it was found that COVID-19 saved lives when the death cases of the disease were compared to the death cases caused by air pollution, where daily death cases reach up to 3287 because of poor air quality. Now, after several months of that report, many countries restarted their activities to survive the economy. Thereby, the infection rate and air pollution are increasing, which yield an increase in death cases. Air pollution was identified as an invisible killer, where it is responsible for deaths by strokes by 24%, heart diseases by 25%, lung cancer by 29%, and lung diseases by 43%. According to the World Health Organization (WHO), 92% of the whole population lives in areas that do not match the minimum standards for healthy air. Two points worth to be mentioned here, first, there are around 3 million deaths annually due to air pollution, where the highest ratio is in China. Second, in most industrial countries, there is a positive relationship between the PM$_{2.5}$ concentration and mortality rate, where the highest rates were in China too (Isaifan, 2020).

Gautam (2020a) reported that NO$_3$ levels in China and India have decreased by around 30% and 70%, respectively, after the lockdown. While in Europe, it decreased by 25% in Spain and 30% in France and Italy during the lockdown. Until May 2020, Asian countries had a better response to the pandemic than European countries, where Europe recorded a sharp increase in infection numbers (Yousif, 2020). A few months later, a huge increase in infection cases was noticed in India, Iran, Saudi Arabia, Pakistan, Bangladesh, and Iraq. Meanwhile, European countries had less increase in infection cases than Asian ones.

Thus, this paper aims to review and discuss the impact of the COVID-19 pandemic on air pollution resulted mainly from industrial and other life activities. In addition, this work provides some insights into the impact of air pollution on the patients who got infected by this virus. In the following sections, we will present the types of pollutants and discuss the results and data provided from different researchers based on countries’ classification due to the differences in the pollutants levels in various areas. Other factors, such as spreading the pandemic (number of cases), the actions were taken by these countries, the economic situation, lockdown period, population, and the availability of the data were also illustrated.

2. Air pollutants

There are many types of pollutants that exist in the air; however, we like to mention the main ones that were discussed within this work.

2.1. Particles matter

This term refers to the ultra-fine particles, whether they are solid or liquid, that disperse in the air. These materials could be made of different components and elements, such as organics, metals, sulfates, nitrates, allergens, and dust. These particles could be the product of fuel combustion in vehicle engines, burning activities for different materials, and industrial discharges. Furthermore, these particles could inherently exist due to natural reasons of dust storms, forest fire, volcanoes, etc. Surely, as the concentration of these particles increases, their impact on beings increases (Cambra-López et al., 2010). There are two common expressions used to describe the type (size) of these pollutants, PM$_{10}$ and PM$_{2.5}$; the subscript number refers to the maximum size of that pollutant in micrometer. The PM$_{10}$ can transfer within the throat, nose, and lungs and cause severe health problems and cardiological and respiratory diseases. More serious, PM$_{2.5}$ could transfer deeper inside the organs and bloodstream and also cause multiple health issues. These effects also depend on the exposure time, where each short and long contact term has its impact and consequences (Slezáková, 2009).

2.2. Ozone

It is a gas that consists of three oxygen atoms, a couple of the normal forms of oxygen, and a single attached to the molecule making
it unstable gas. This gas is naturally found among the atmosphere layers, between the troposphere and stratosphere, and extremely contributes to protecting beings from the ultraviolet radiation received from the sun. However, ozone is a double-edged gas, where rising its concentration near the earth’s surface influences human health negatively. The low layer ozone is produced from the reaction of industrial and transportation facilities discharges with sunlight, and it could transfer far away from the main source (Cohen et al., 2018).

2.3. Nitrogen dioxide (NO₂)

It is a reactive gas yield mostly from the industry, transportation facilities, and other heating activities. The NO₂ can highly be concentrated near crowded streets, while its indoor sources are the unflued gas heaters, smoking, and stoves. In addition to the risks that this gas causes to humans’ health, particularly for the respiratory system, it helps in the generation of ground-level ozone and PMs. In polluted cities, it can clearly be identified as a radish-brown layer appears in the surrounding (Vardoulakis et al., 2020).

2.4. Carbon monoxide (CO)

Similar to other pollutants, CO is generally formed from the industry and engines, where it is a product of the incomplete combustion processes. Domestically, it can result from fireplaces, smoking, gas heaters, and stoves. It is a colorless, odorless, and toxic gas. Once it is inhaled, it reacts with the blood’s oxygen and causes harm to the organs, particularly the heart and brain, whereas a high concentration of this gas is deadly. The cold weather enhances carbon monoxide generation because low temperatures generate an uncompleted burning process (Gholami et al., 2020).

2.5. Sulphur dioxide (SO₂)

It is an extremely reactive gas, known for its rotten smell, produced from industrial sources that burn fossil fuel. Also, there are natural resources of this gas as volcanos, sea sprays, and organic materials decay. Similar to other pollutants, SO₂ affects people’s health and causes irritation to the nose, throat, and lungs, and aggravates cardiovascular diseases (Pattantyus et al., 2018).

3. Literature research methodology

Works that studied the change in air pollution during COVID-19 lockdowns reported data from different resources depending on the available facilities. For instance, Kotnala et al. (2020) gathered the data from local air monitoring stations, where these stations are official and belong to the Central Pollution Control Board (CPCB) of New Delhi. While Gautam et al. (Gautam, 2020a) used information received from the National Aeronautics and Space Administration (NASA) to study the change in air quality in India. In China, a similar procedure was followed, and a combination of ground indicators and satellite information was applied (Fan et al., 2020).

Data collection had various forms; some researchers analyzed data on a yearly basis, including short or long-term eras, while others studied it using different time bases. Moreover, some studies included data from the whole year, while others focused on a certain season and compared it with 2020. Also, the numbers could be the average of daily tracking or any other time-base scale. This information could differ from a place to another even within the same country, where cities could have more probes than rural counties. Hence, the reported studies could include a limited number of locations (tens) or could be more comprehensive (hundreds and thousands). In countries like the US, researchers obtained the data from multiple resources, such as NASA, satellites, local air stations, environmental protection agency, etc. Similar approaches were in Europe, where the European Space Agency was one of the main sources.

It is good to notice that many researchers considered the impact of air pollutants on COVID-19’s infections and deaths. However, some research included the effect of indirect factors, in addition to the pollutants’ influence. Examples of the indirect factors include, but are not limited to, the population, household income, the first confirmed case date, and hospitals’ availability and capacity.

4. COVID-19 impact on countries

4.1. India

COVID-19 was firstly confirmed in India on January 30th, 2020; later, a sudden jump in the confirmed cases happened on March 4th. Starting from March 16th, all places of mass gatherings, such as institutions, shopping malls, and theatres, were closed across the country. This emergency lockdown turned to an essential step in the environment recovery, where emissions sources were restrained in this quick action, while the world is concerning about effective policies for emissions mitigation. As mentioned before, the lockdown made a significant decrease in air pollutants contaminations, which gave the opportunity for researchers and governments to understand the background and future plans of pollution control. Kotnala et al. (2020) found that the pollution rate has decreased in the Delhi area more than in other areas due to applying the lockdown. Their findings were based on the data collected from 12 air pollution monitoring stations that belong to the Central Pollution Control Board (CPCB) in New Delhi. The particulate matter of the size of 2.5 and 10 μm (PM₂.₅ and PM₁₀, respectively) decreased by 200%. Also, nitrous oxides (NOₓ) concentration decreased from 342 ppb on Jan 12th, 2020 to 24 ppb on Mar 30th, 2020 in CRRI–Mathura Road, Delhi, which means around 1400% reduction. Fig. 1 shows the levels of PM₂.₅, PM₁₀, NOₓ, and CO pollutants.
Fig. 1. (a) PM$_{2.5}$ concentration, (b) PM$_{10}$ concentration, (c) NO$_x$ concentration, (d) CO concentration during COVID-19 lockdown period in Delhi (Kotnala et al., 2020).
before and after the three weeks of lockdown at four locations in Delhi. The huge drop in contaminates levels is obvious even within that relatively short period.

The impact of the lockdown on air pollution in India was also studied by Sharma et al. (2020). Six pollutants, PM$_{10}$, PM$_{2.5}$, CO, NO$_2$, ozone, and SO$_2$, were considered to assess air quality in 22 cities covering different regions of India. Compared to other pollutants, PM$_{2.5}$ showed the maximum reduction (43%) in most regions. About 31, 10, and 18% reduction in PM$_{10}$, CO, and NO$_2$ were measured during the lockdown period. On the contrary, O$_3$ concentration showed an increase of about 17% and a negligible change of SO$_2$ level was recorded. The increase in O$_3$ could be attributed to reducing the particulate matter besides the decrease in NO$_2$. They concluded that weather conditions could have a significant negative impact on air quality despite the lockdown; PM$_{2.5}$ concentrations could increase due to unfavorable weather conditions.

Some researchers tried to specifically identify the effect of the pandemic on PM$_{10}$ produced from rock quarrying and crushing, of forced lockdown. A PM$_{10}$ value of more than 100 $\mu$g/m$^3$ is considered very harmful to humans, wildlife, and climate, according to the Central Pollution Control Board (CPCB). In India, the PM$_{10}$ value is often high; yet, this amount was substantially decreased with the partial closing of quarrying and crushing units, which was good for human safety. Small dust inhalation particles also result in different respiratory problems over the long term as reported by the WHO reports. The global lock-off offered a fair chance of understanding our stresses and resilience regarding our existence; good control of emissions sources will grant a healthy planet (Mandal and Pal, 2020).

Mahato et al. (2020) discussed the case of air quality at the time of quarantine, with an especial link to the world’s megacity of

![Fig. 2. The concentration of the aerosol for the period between March 31st, 2016, and April 5th, 2020 in India (Gautam, 2020b).](image-url)
Delhi. This is a valuable contribution to legislative authorities because environmental regulation aims to attenuate air pollution. Information from air quality was expressed in the large cities based on seven categories of contaminants, PM$_{10}$, PM$_{2.5}$, SO$_2$, NO$_x$, CO, O$_3$, and NH$_3$. Before and during the lockdown periods, the National Air Quality Index (NAQI) was used to illustrate the spectrum of air quality. During the activity restriction duration in the megacity, a large decrease in NAQI is observed. The maximum reduction followed the order NO$_2$, CO and NH$_3$ was observed. On the opposite, the concentration of O$_3$ is expected to increase significantly, owing in particular to the decrease of the NO$_x$ and particulate matter concentration. Only one day after establishing the lockdown, the air quality increased by nearly 40%. The findings of this study could help to decide whether setting a lockdown serves as an effective strategy to preserve the atmosphere and provide local residents with a better ecosystem. Nevertheless, the outcomes should rigorously be analyzed to determine the proper regulation mechanisms. A detailed study of the seasonal changes in air quality concerning regional meteorological factors once or twice a year, in a long-run cycle, would also be suggested to promote the effective exploitation of these lockdowns.

Worldwide governments, including India, and public health authorities have imposed quarantine and reduced communication as a try to reduce the number of infections and prevent the spread of COVID-19 in communities. These restrictions led people to stay at home for a long time and increased exposure to indoor air. The WHO reported that approximately about 3.8 million deaths in 2016 happened due to exposure to polluted indoor air. Indeed, poor quality indoor air comes from smoking, cooking fire, poor ventilation, and using chemicals, especially volatile chemicals (Hadi et al., 2020b; Alalwan and Alminshid, 2020; Alminshid et al., 2021). Therefore, the quarantine leads to remain indoors for a long time, this associates serious diseases, like lower respiratory acute infections, chronic obstructive pulmonary disease, cardiovascular illness, lung cancer, and asthma (Ansari and Ahmadi Yousefabad, 2020).

Gautam (2020b) reported the effects on environmental and public health because of the lockdown. According to the data obtained from NASA, a 50% decrease in air pollutants was observed after the lockdown in India. Fig. 2 shows the concentration of the aerosol for the period between March 31st, 2016, and April 5th, 2020 in India. From the figure, it can be noticed that there are three areas, dark brown, tan, and light yellow that display the aerosols concentration. The results show that there is an improvement in the air quality after applying the quarantine and stopping the human activities, which improves the total health (Gautam, 2020b).

4.2. China

Since COVID-19 turned into a global pandemic by the end of 2019, the change in the pollutants’ emission was decisive to know the impact of the pandemic on the social life, air pollution, and economy. The sudden outbreak of the virus in China in January 2020 had many impacts, where most factories were shut down, transportations were decreased, and people were forced to stay home. This resulted in a reduction in the emission and greenhouse gases in many areas of the country.

Zhang et al. (2020) used the TROPOMI instrument to estimate the change in NO$_x$ emission in China for three different periods in three different areas at the beginning of 2020. It was found that the districts have been affected differently in the period between January 1st and March 12th, 2020. There was a recovery from NO$_x$ emissions in east China until March 12th, while Wuhan displayed non (Zhang et al., 2020).

Fan et al. (2020) also used the monitoring instrument TROPOMI to measure the tropospheric emission gases concentrations and the aerosol optical depth (AOD) to measure the aerosol amount. Based on the data that were taken from the satellite and ground indicators, the effect of COVID-19 on the environment was clear. To obtain this aim, data of 30 days before the Chinese New Year festival and 60 days after it for the years 2017–2020 were analyzed. Results showed a large reduction of pollutants; particularly, the tropospheric total Vertical Column Densities (VCDs) NO$_2$ decreased by 80% in some regions. COVID-19 added an additional reduction of up to 70% in highly populated areas with heavy human activities. However, both effects were very small in rural and low-density population areas; ground-based in situ findings from 26 rural counties provided data of CO, NO$_2$, O$_3$, SO$_2$, PM$_{2.5}$, and PM$_{10}$ levels. These data focused on Wuhan and were analyzed based on the daily average concentrations. In previous years, NO$_2$ levels were reduced a few days before the Festival and were then enhanced after about two weeks, whereas in 2020, those maintained low. Similar behavior was performed by SO$_2$, while CO, PM$_{2.5}$, and PM$_{10}$ also reduced during the celebration but had a different behavior than NO$_2$ and SO$_2$. From an atmospheric chemistry view, it is anticipated that ozone levels were increased. Analyzing the outcomes of the Chinese largest event and COVID-19’s impact was difficult because of the meteorological conflicts (Fan et al., 2020).

The quality of air has become a concern to the Chinese public health organizations and government. Xu et al. (2020) investigated air quality in three towns in Hubei province/China (Wuhan, Jingmen, and Enshi) located in the middle of the country. A comparison for the period January–March was conducted for the years 2017–2020, which included the quarantine and actions taken. The results showed the concentrations of emission gases in the three cities in January 2020 were less than in January of previous years. Also, it was noteworthy to study the change in the concentration of atmospheric O$_3$. In the three cities, the concentration of atmospheric O$_3$ through the first three months of 2020 was much higher than in 2017–2020. This is due to the reduction in NO$_2$; this hinders the interaction that occurs between O$_3$ and NO. It can be concluded that the improvement in air quality is due to compliance with the quarantine instructions and the decrease in industrial production. However, a general decline in air contaminations during the months of February and March in the year 2020 was observed (Xu et al., 2020).

When the infection spread in China, the economic activities had a sharp reduction, which resulted in a decrease in the contamination emission. The reduction in NO$_2$ levels in the air before and after the quarantine is shown in Fig. 3 (Gautam, 2020a). In March 2020, it was reported that the mortality rate of COVID-19 is less than half of the mortality rate of air pollution (Isaifan, 2020). Shi and Brasseur (2020) compared the data of 800 locations all around China before and after the lockdown, where the lockdown continued from January 23rd to February 29th, 2020. Results showed that PM$_{2.5}$ and NO$_2$ levels in the north part of China were reduced by...
around 29 ± 22% and 53 ± 10%, respectively.

On the other hand, the ozone level has improved by around 200%. Similar findings were recognized in Wuhan, where PM$_{2.5}$ and NO$_2$ levels dropped by 31 ± 6% and 54 ± 7%, respectively, and ozone levels enhanced by 220%. These results were obtained from 10 locations. Other contaminations, such as SO$_2$ and NO$_x$, had the same behavior, where a remarkable decrease was noticed. However, with all these reductions in contamination levels, particularly NO$_x$ and PM$_{2.5}$, and improvement in ozone concentration, it was found that the ozone problem was not totally relieved.

Chen et al. (2020a) investigate the air pollution and mortality rate, where 367 cities in China were involved. It was found during the quarantine that the nitrogen dioxide level reduced by 12.9 μg/m$^3$, and in Wuhan by 22.8 μg/m$^3$, while PM$_{2.5}$ reduced by 18.9 μg/m$^3$ in the involved cities and by 1.4 μg/m$^3$ in Wuhan particularly. These results were confirmed with the Copernicus Sentinel-5P satellite pictures.

This improvement in air quality during the lockdown had a positive effect on people’s health, where it was estimated that 8911 lives were saved, 65% of them have cardiovascular and chronic obstructive pulmonary diseases. Also, PM$_{2.5}$ reduction led to a decrease in the death cases by 3214, 73% among them with the previously mentioned diseases. Similar findings were observed by Rajagopaian et al. (2020), where a decrease in mortality rates was noticed due to the improvement in air quality during the quarantine.

Wang et al. also investigated the outbreak of COVID-19 and its effect on air pollution in Wuhan city (Wang and Su, 2020), where the first case of COVID-19 was recorded. The nitrogen dioxide was used as an indicator to assess the air pollution levels. NO$_2$ mostly comes from the combustion of oil, coal, natural gas, and other fuels and the exhaust of urban vehicles. A lockdown was announced in Wuhan on January 23rd, 2020. A week before the lockdown, the concentration of NO$_2$ was reported at high levels, while a week later (on January 30th) the NO$_2$ emissions were reduced significantly not only in Wuhan but countrywide. This was attributed to the large industrial plants situated in Wuhan, which produce large amounts of polluting gases. However, since the end of February 2020, the concentration of NO$_2$ started to increase gradually. This is because industrial production activities have resumed activity after the Chinese government allowed the industrial enterprises to restart since the epidemic gradually became under control. Fig. 4 shows changes in NO$_2$ emissions in Wuhan as reported by the National Aeronautics and Space Administration (NASA) (Wang and Su, 2020).

Wang et al. reported that although most of the anthropogenic activities were reduced in Wuhan due to the outbreak of coronavirus on January 23rd, 2020, the North China area still has high levels of air pollution (Wang et al., 2020). PM$_{2.5}$ was chosen to assess air quality using the Community Multi-Scale Air Quality (CMAQ) model. This research highlighted that reductions in anthropogenic activities (mainly transportation and industry sectors) would not help to avoid severe air pollution in China, where the decrease in PM$_{2.5}$ concentrations was not enough to noticeably improve air quality conditions.
Fig. 4. Changes in nitrogen dioxide emission levels in China (Wang and Su, 2020).
Fig. 5. The reduction in NO$_2$ concentration in France, Italy, and Spain during the lockdown (Gautam, 2020a).
Ma et al. studied the correlation between COVID-19 mortality and air pollution from aside, and weather conditions from another side for the period from 20 January 2020 to 29 February 2020 in Wuhan (Ma et al., 2020). Meteorological parameters that were explored included temperature, humidity, and diurnal temperature. This study reported that temperature is positively associated with the daily mortality of COVID-19 in China but negatively with relative humidity. The effect of air pollution was not studied in detail in this research.

Zhu et al. (2020) investigated the relationship between ambient air pollutants and the infection caused by the novel coronavirus. Six air pollutants (i.e., PM$_{2.5}$, PM$_{10}$, SO$_2$, CO, NO$_2$, and O$_3$) were analyzed for the period from January 23rd, 2020 to February 29th, 2020 in China (Zhu et al., 2020). The results of this paper found that there is a statistically significant relationship between COVID-19 infection and air pollution. Exposure to high concentrations of PM$_{2.5}$, PM$_{10}$, CO, NO$_2$ and O$_3$ led to increasing the possibility of COVID-19 infection, while exposure to SO$_2$ resulted in a lower risk of COVID-19 infection.

Bao and Zhang highlighted the importance of understanding the role of green production and consumption using statistical and quantitative analyses. Least Square Dummy Variable (LSDV) and regression-discontinuity design (RDD) methodological approaches were applied to the concentrations of five air pollutants, SO$_2$, PM$_{2.5}$, PM$_{10}$, NO$_2$, and CO, to understand the relationships among air quality, human mobility, and travel restrictions. They found that air pollution is affected by environmental conditions; thus, the adoption of travel restrictions due to the lockdown greatly reduced air pollution in 44 cities in northern China. The air quality index (AQI) decreased by 7.80% during the lockdown compared with a regular day. The concentrations of the SO$_2$, PM$_{2.5}$, PM$_{10}$, NO$_2$, and CO decreased by 6.76%, 5.93%, 13.66%, 24.67%, and 4.58% respectively. The ratio of reduction among air pollutants varied widely. The larger declining ratio of PM$_{10}$ and NO$_2$ was attributed to the source of the pollutants. Besides the relation of human behaviors on air quality, the environmental temperature signed a major impact on air pollution. The temperature rise could also induce air emissions to rise. SO$_2$ and NO$_2$ concentrations were significantly negative but positive with AQI, PM$_{2.5}$, PM$_{10}$, and CO. In particular, the reduction of AQI, PM$_{2.5}$, and CO were partially mediated by individuals movement, but SO$_2$, PM$_{10}$, and NO$_2$ were fully mediated (Bao and Zhang, 2020).

Li et al. reported the measurement of air pollutants to change due to various aspects of human operations in the Yangtze River Delta area (in eastern China). The effect of SO$_2$, NO$_2$, PM$_{2.5}$, and volatile organic compounds (VOCs) was studied. Evidence from the production sources suggests that PM$_{2.5}$ is mainly discharged from the industrial sector. There are also other sources that release PM$_{2.5}$ including mobile, emissions, residences sources, and long-range transport coming from northern China. Results show that because of the restricted human activities and lowered anthropogenies emissions, PM$_{2.5}$ reduced by 25.4%–48.1% during the first level period (the strict period) and by 15.3%–36.0% during the second level period (when restrictions on normal activities were loosened to some extent).

Regarding SO$_2$ and NO$_2$ concentrations, they were reduced by 17.9%–41.3% and 32.5%–70.3% during the level I response period; 12.0–27.0% and 3.3%–17.0% during the Level II period. On the other hand, Ozone concentration showed an increasing trend due to lockdown, as opposed to the decrease of other pollutants. This trend can be explained by decreasing NO$_x$ emissions and thus declining O$_3$ titration by NO during lockdown (Li et al., 2020).

### 4.3. The United States

The US is the most affected country by COVID-19, where the case numbers reached more than 7.5 M in late September 2020 and around 30 M in late February 2021. However, Brandt et al. (2020) studied the relationship between air pollution and COVID-19 seriousness. Also, they showed that different races were influenced by different rates and the infection depending on the density of the population. It was found that high population density cities, such as New York and Detroit, had a higher infection even after the lockdown, as opposed to the decrease of other pollutants. This trend can be explained by decreasing NO$_x$ emissions and thus declining O$_3$ titration by NO during lockdown. 

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The US is the most affected country by COVID-19, where the case numbers reached more than 7.5 M in late September 2020 and around 30 M in late February 2021. However, Brandt et al. (2020) studied the relationship between air pollution and COVID-19 seriousness. Also, they showed that different races were influenced by different rates and the infection depending on the density of the population. It was found that high population density cities, such as New York and Detroit, had a higher infection even after considering the infection cases ratio to total population. However, in some cases, this was not applicable. For instance, in New York, although Manhattan’s population is higher than Bronx’s one, Bronx had double infection cases and mortality than Manhattan. Here, another factor is affecting the transmitting of the virus, which is related to the racial disparities, since around one-third of the Bronx’s population are Blacks and Latino who live under the poverty line.

In Michigan State, it was found that one-third of the cases and 44% of the mortality were blacks, though their population is 14% in that state. Particularly in Detroit, around three-fourth of the total mortality were blacks. Chicago is another example, where it was found that half of the cases and around 70% of deaths were blacks, although their population is around 30%. Similarly, in Louisiana, the black’s population is around one-third, but their mortality rate was 61%. In general, the blacks had a double mortality rate compared to their population demographics.

Here, it was indicated that minor race communities experienced worse infection conditions. This could be attributed to low and packed housing conditions. Also, they usually work in crowded areas with low aeration conditions or polluted environments. Furthermore, they have lower access to health care and consuming non-healthy food, and use public services for transportation, sanitation, etc. This could be the reason to have these high infection and mortality rates. It is good to mention that there are around 141 million people only in the US who live in air-polluted areas. The long-term exposure to polluted air enhanced the chance to have severer symptoms of COVID-19. Studying the relationship between the infection rate and race, income, population density, and other socioeconomic factors is needed to identify the virus’s infection.

The relationship between PM$_{2.5}$ and death cases of 3089 counties across the US were studied, where this study coved 98% of the total population. Findings showed a proportional link between the area’s PM$_{2.5}$ exposure history and COVID-19 mortality rates when PM$_{2.5}$ data in the period 2000–2016 were compared. Among the covered counties, it was noticed that 1244 counties (40.3%) had no death cases up to Jun 18th, 2020, which was attributed to low PM$_{2.5}$ exposure. Also, as the PM$_{2.5}$ long-term average concentration increased by 1 µg/m$^3$, the average COVID-19 death rate increased by 11%. Similar to other studies dealt with the US, it was found that
the mortality cases were higher in black residents, which was attributed to different reasons of population density within the household, median income, and work environment. The scientific reason for PM$_{2.5}$ impact on humans’ bodies is its ability to over-express the angiotensin-converting enzyme 2 (ACE-2) receptors, which leads to host more viruses and weaken the humans’ immunization. As a result, the lungs could ruin, a reduction in oxygen and other failures occur, and death could take place (Wu et al., 2020).

In another study, the relationship of COVID-19 mortality rates with four pollutants, namely: ground-level ozone, NO$_2$, SO$_2$, and CO, were studied across the US. The data sources were the Environmental Protection Agency, the US Census Bureau, and other authorities. The researchers considered the confounder variables that influence the findings; these are the hospital beds, population density, average income, and period since the first recorded case in that place. The main finding was ground-level ozone and NO$_2$ are directly related to mortality rates in counties, and specifically to COVID-19 mortality. Here, environmental restrictions were recommended to be applied as the facilities resume their activities (Ji and Li, 2020).

When long-term data of 28 tracking air pollution stations across the US were analyzed, results showed different reduction rates of NO$_2$ and CO during the lockdown. Findings from 2/3 of the stations monitored a big decrease in the NO$_2$ and CO concentrations, 49% and 37%, respectively, where these ratios are higher in high population places. A similar decline was recorded for PM$_{2.5}$ and PM$_{10}$ in the big cities of Nevada, California, and the northeast coast, while the reduction in O$_3$ was slight. The huge reduction in NO$_2$ and CO concentrations was attributed to the transportation and other activities suspension during the lockdown, where this reduction was clearer in the urban areas than in suburban. As that situation was temporary and could fade when the lockdown is ended, the authors recommended putting efforts to force the environmental protection laws and encouraged clean fuel transportation facilities (Chen et al., 2020b).

4.4. Italy

It was found that the most polluted cities in Italy were the industrial cities, namely, the Po valley, Bergamo, Cremona, and cities of Lodi (Frontera et al., 2020). Fig. 5 shows the reduction in NO$_2$ concentration in France, Italy, and Spain during the lockdown (Gautam, 2020a).

Bontempi et al. investigated the association between air pollution and the rapid diffusion of COVID-19 in Lombardy, where COVID-19 was firstly recorded and then widely spread in Italy (Bontempi, 2020). Concentrations of PM$_{10}$ in the north of Italy were analyzed to quantify air pollution for the period from 10th February to March 27th, 2020. The results of this paper showed that COVID-19’s reported cases in the north of Italy were not correlated to the concentration PM$_{10}$, the rapid diffusion of coronavirus in Lombardy was not attributed to the air pollution caused mostly by the industrial activities in the region.

Conticini et al. investigated the relationship between air pollution in northern Italy and the syndrome of acute respiratory. Actually, two regions in Italy (Lombardy and Emilia Romagna) were among the highest places in the world in the number of death cases, knowing that they are among the highest polluted areas in Europe. It was found that people who live near polluted areas are more susceptible to respiratory infections. Furthermore, long exposure to polluted air will lead to chronic inflammatory disease. Thereby, it was concluded that the reason for the high infection rate in Italy goes back to the high pollution rate in the northern area of that country (Conticini et al., 2020).

Sciomer et al. noticed that by monitoring the infection rate in Italy, as well as other countries, air pollution has a big role in the spread (Sciomer et al., 2020). Several possible factors in the environment were considered regarding the transmission of the virus. Han et al. reported that contact among humans and the spread droplets represent the best way to transmit the virus. They mentioned that COVID-19 could survive on hard surfaces and in the air for a relatively long time (Han and Yang, 2020). It is good to mention that pollution kills 3 to 7 million people and wastes 1 trillion US dollars annually worldwide because of the increased industrialization and fast deterioration in the environment (Niemann et al., 2017). With COVID-19, these numbers intend to increase to an unknown level since we are still facing this disease. Although several vaccines and treatment drugs were identified recently, none of them can treat the disease 100%. Another obstacle is the genetic modulation that the virus could take, where notable changes in the RNA of the virus happens as in the case of the novel coronavirus.

The association between long-term exposure to NO$_2$ and COVID-19 fatality in Italy, Spain, France, and Germany was examined by Ogen et al. (Ogen, 2020). The Sentinel-5 Precursor space-borne satellite was used to monitor the NO$_2$ concentration in the troposphere for two months (January–February 2020) before the outbreak of COVID-19 in Europe (Ogen, 2020). Satellite data of the tropospheric NO$_2$ over Europe showed that a big hotspot of elevated concentration of NO$_2$ was recorded in the north of Italy. This region was also had the highest fatality due to coronavirus. This paper concluded that long-term exposure to NO$_2$ increases the fatality rate of COVID-19. This is attributed to the fact that exposure to NO$_2$ causes inflammatory in the lungs and consequently increases the risk of death caused by COVID-19.

4.5. Brazil

The first COVID-19 case in Brazil was confirmed on February 25th, 2020. On March 16th, the state’s governor declared a public health emergency in the city of Rio de Janeiro, and partial lockdown measures came into force a week later.

Dantas et al. discussed the effect of the partial lockdown in Rio de Janeiro on the air quality of the city by comparing the concentrations of PM$_{10}$, CO, NO$_2$, and O$_3$ before and after the partial lockdown (Dantas et al., 2020). Results showed that the concentrations of PM$_{10}$, CO, and NO$_2$ decreased during the lockdown while O$_3$ increased. The reduction in NO$_2$ is clearly related to emission reduction that is caused by diesel vehicles, local and interstate buses, air flights, and cruises. The sharp decrease in CO was mainly attributed to the decrease in light-duty vehicular flux during the lockdown. Besides these reasons, the decline in PM$_{10}$ is related to the...
reduction or shutdown of the metallurgical and steel industries and mining and construction businesses which are located in the region. Ozone concentrations increased probably due to the decrease in nitrogen oxides level.

To determine differences in air pollutants concentrations during the partial lockdown, observations from four air quality stations in São Paulo were explored. In the urban sector, major changes have been seen in air quality for NOx, NO2, and CO gases in areas heavily affected by traffic decreased by ~77.3%, ~54.3%, and ~64.8%, respectively. In comparison, in urban areas less influenced by vehicle travel, the rate of nitrogen monoxide reductions was around 30%. Furthermore, a rise of nearly 30% in ozone concentrations was reported that potentially linked to reductions in nitrogen monoxide. However, minor improvements were noticed in the industrial sector, where a decrease in the volume of all contaminants was evaluated compared with the pre-partial locking period. This can be related to the fact that the industry was not forced to lock, while a decline in demand has impacted many industrial sectors. In urban areas, there has been a substantial change in the air quality as a reduction in air emission was tracked in traffic areas (Urban Road I, Urban Road II, and City Center). Recent research showed that the main source of 68% of NOx and 98% of CO emissions are heavy-duty diesel truck emissions.

Vehicle traffic decreased dramatically in all Brazilian areas during the partial lockdown, which positively affected the air quality. Though, pollutants reduction was not strongly influenced multiply. While the partial lockout led to a beneficial impact on air quality, it is necessary to take into consideration the adverse impacts on social factors, such as the deaths caused by COVID-19 and even the drastic economic consequences. The pandemic showed that eliminating the possible air pollution sources that can be replaced by remote technologies is a mandatory step now and in the future (Nakada and Urban, 2020).

Emissions to mitigate NOx can also minimize global change, as NOx is often released in combination with climate energy, e.g. carbon dioxide and black carbon (BC) fine particles. At all stations in Brazil, a significant drop was reported varying from 34 to 68%. According to the scientists, the variation in NOx decline can be attributed to distances variety between sampling sites and main roads, interstice volatility of the gas, as well as specific traffic patterns. As the rates of NOx and BC in regions of strong traffic control are strongly associated (Krecla et al., 2020), their concentrations are anticipated to decline equally when traffic intensity decreases. This indicates that implementing stricter automotive pollution regulations will contribute to a significant air quality change in the MASP (Metropolitan Area of São Paulo). Although high duty diesel vehicles (HDDV) only account for 3.1% of the on-road fleet, their high emissions of 12.4 (Euro III equivalent) represent a serious danger. Therefore, several measures concerning the HDDV should be taken, including applying a higher emissions limit (Euro-VI equivalent), renewal of the fleet of public buses, and implementing regular inspections and maintenance (I/M) programs, for vehicles, particularly for urban small and medium-sized vehicles. Eventually, automobile pollution mitigation has been frequently debated as an effective step to reduce concentrations of air contaminants in cities (Krecla et al., 2020).

Siciliano B. et al. address the consequences, as a result of the reduction in primary contaminants concentrations, VOC and NOx, and improvements in the major pollution sources, of the partial lockout on the ozone rates of Rio de Janeiro. On February 25th, 2020, the first outbreak of COVID-19 in Brazil was verified, while on March 23rd, limited lockout legislation came into practice. During the first partial lockdown week, the levels of CO and NO2 showed substantial decreases; though, for all analyzed places, ozone rates have risen (Siciliano et al., 2020). Increased ozone concentrations could be attributable to the increase in the non-methane hydrocarbon (NMHC)/NOx ratio in social distance measures because atmospheric chemistry is controlled by the VOCs in Rio de Janeiro. Furthermore, it increased multiply as air masses have arrived from the manufacturing areas since these masses contain high NMHC/NOx levels and aromatic compounds that highly decrease the reactivity of VOC.

As social separation was recommended but not mandatory, people’s responses varied in different areas of the city but mainly reduced during the first two weeks of April. However, ozone and NMHC/NOx ratios increased during the partial lockdown as a general trend, where high temperatures and sunlight are beneficial to produce ozone. The main source of approximately 91% of NOx in cars is diesel vehicles (buses and trucks) based on a national vehicle inventory. In comparison, NMHC is largely driven by light-duty vehicles (46%) and motorcycles (25%) (Siciliano et al., 2020).

The partial locking process slightly decreased the number of busses, while the trucks continued to operate as industrial activities, construction, food, and freight retained. In the first two weeks of the lockdown, the traveling of passenger cars decreased to around 70–80% (Dantas et al., 2020), but then raised to 50%. A higher decrease in NMHC would be anticipated when considering automotive pollution; this suggests that other factors have related strongly to the NMHC levels. Air quality policy challenges are difficult to overcome because of the dependence of ozone levels on NMHC/NOx ratios and VOC speciation. As mentioned above, high temperatures and solar irradiation support the atmospheric processes contributing to O3 production in tropical cities such as Rio de Janeiro.

Recent studies and other surveys across the globe indicated a fast decline when the roads and main contaminants were controlled. A thorough study of NMHC/NOx ratios and air mass trajectories in the town of Rio de Janeiro showed very large concentrations of ozone were produced due to the high proportions (because of a stronger drop in NOx relative to hydrocarbons) and the improvement in the reactivity of VOCs. Although these findings may be local and linked to unique topographical and environmental conditions of the town as well as the feedback of industrial pollutants in the region, other metropolitan areas may be influenced by similar circumstances. The general conclusion that air quality has been improved during lockdown should be considered carefully to cover all the pollutants that have an impact on human health, supported by several scientific literatures and publications. Lowering the particulate and NO2 amount is definitely a beneficial outcome of the social dissociation and lockout steps, but it is important to recognize these negative environmental consequences. Ultimately, these observations show the significance of NMHC surveillance and speciation. An important idea for potential debates appears to be the prospect of using NMHC in air quality requirements (Siciliano et al., 2020).
4.6. Malaysia

The first coronavirus case in Malaysia was recorded on January 25th, 2020, and the number of cases continues to increase since March 2020. As a result, the Malaysian government implemented the 2020 Malaysia Movement Control Order (MCO) that included different procedures to restrict the movement of people and vehicles. This step was an attempt to isolate COVID-19 and reduce its diffusion among people.

The effect of MCO on air pollution using PM$_{2.5}$ as an indicator to assess air quality in Malaysia was studied by Abdullah et al. (2020). This paper concluded that PM concentrations were reduced after the implementation of MCO; some areas showed a reduction of up to 58.4%. This is due to the fact that during MCO, traffic density and industrial emissions have reduced, leading to a reduction in PM$_{2.5}$. However, the authors declared that the weather conditions most likely have a significant effect that needs to be studied in future studies.

The influence of COVID-19 lockdown on the Spatio-temporal variability of key air contaminants PM$_{10}$, PM$_{2.5}$, NO$_2$, SO$_2$, and CO in Malaysia, were investigated by Bao and Zhang (2020). An assessment of major pollutants sources in Malaysia over the COVID-19 timeframe was provided, including manufacturing, power plants, transportation, domestic cooking and heating, and agricultural operations. This work compared PM$_{10}$, PM$_{2.5}$, NO$_2$, SO$_2$, CO, O$_3$ levels in the period of March 18th to April 30th of years 2018, 2019 and 2020. During the MCO period, the analysis showed a significant decrease in the concentration of PM$_{10}$, PM$_{2.5}$, and NO$_2$ in industrial by 28–39%, 19–42%, and 33–46% and urban sites by 26–31%, 23–32%, and 63–64%, respectively. The combustion restriction has also minimized carbon monoxide, which is a major contaminant from insufficient combustion sources (vehicle traffic and biomass burning). The reduction percentage of CO was 25–32% and 25–27% at the urban and suburban sites, respectively. The largest sulfur-induced pollutant is SO$_2$, which is primarily emitted from anthropogenic pollution of fossil-fuel combustion. The reduction of SO$_2$ was 9–20% in urban and 17–19% in suburban sites.

4.7. Southeast Asia (SEA)

NO$_2$ is mostly produced as NO from burning fuel, such as automobile exhaust systems, manufacturing, power plants, and domestic heating. NO$_2$ is a combustion tracer produced from human activity, and it is a source of aerosol and ozone nitrate. Aura-OMI satellite sensor measurements generally demonstrate a drop in NO$_2$ concentrations compared to the average in 2015–2019 for most areas of the SEA region in March and April 2020. In big cities such as Manila, Bangkok, Kuala Lumpur, and Singapore, the highest decline is reported. On the other hand, in March 2020, the significant rise in NO$_2$ emissions in the northern part of the SEA was recorded due to strong forest and farm fires. NO$_2$ level rose by around 1% and 3% relative to its level in 2015 and 2019 in Ho Chi Minh (Vietnam) and Yangon (Myanmar), respectively (Devi et al., 2020).

4.8. Studies from more than one country

Nearly half of the world was locked in part or entirely due to the COVID-19 outbreak. In a study by Devi et al., direct and indirect environmental impacts of the COVID-19 global outbreak were investigated using the global tropospheric pollutants NO$_2$, CO, and Aerosol optical depth (AOD). The data were provided by the Spatio-temporal satellite during January–March 2020 (Devi et al., 2020).

The weekly data collection in this period showed a sharp decline in NO$_2$ concentrations around the world, mainly in Southern Hemisphere and tropical regions. This trend can be attributed to the shutdown of various industries at the period of the outbreak of COVID-19, as well as global wind circulation. The highest decrease in NO$_2$ concentration was recorded in western Africa, southern Asia, and south-eastern Asia.

The main reason for the high CO concentration is the incomplete burning of carbon-based fuels and bushfires in some countries, which spreads by wind circulation throughout the lower atmosphere. A significant reduction in CO concentration was observed in the northern part of India due to the effective implementation of the shutdown of major industries in response to the global pandemic in 2020. The study exhibited a low-moderate reduction of AOD in central and western Africa, India (IGP), eastern China, and southern regions of South America. This decrease represented a clear implication of human activities suspension after the COVID-19 outbreak (Lal et al., 2020).

Muhammad et al. studied the impact of the lockdown in China, Spain, France, Italy, and the USA on air pollution (Muhammad et al., 2020). Data on NO$_2$ concentrations were collected from different sources and analyzed to assess air quality. The authors of this paper claimed that COVID-19 is considered as “Blessing in Disguise”, where air pollution has reduced during the lockdown in many regions worldwide. However, this positive effect on the environment is temporary but governments and individuals should learn from this lockdown how to reduce pollution on a long-term basis.

Similarly, Sicard et al. (2020) compared the seasonality of daily mean concentrations O$_3$, NO$_2$, NO, PM$_{2.5}$, and PM$_{10}$ between Europe (Nice, Rome, Turin, and Valencia) and China (Wuhan) cities. When traffic stations were analyzed separately, it was observed that the highest and lowest mean concentrations for the various pollutants were: for O$_3$ in Wuhan 54.1 μg m$^{-3}$ and in Turin 37.3 μg m$^{-3}$, for NO$_2$ in Turin 40.8 μg m$^{-3}$ and in Valencia 21.5 μg m$^{-3}$, for NO in Turin 25.6 μg m$^{-3}$ in Nice 10.6 μg m$^{-3}$, for PM$_{2.5}$ in Wuhan 43.1 μg m$^{-3}$ and in Valencia 11.3 μg m$^{-3}$, and PM$_{10}$ in Wuhan 56.1 μg m$^{-3}$ and in Valencia 21.1 μg m$^{-3}$, respectively.

During the lockdown, the change in daily O$_3$ concentrations at all traffic stations was associated with a strong decline in NO$_2$ concentrations compared to baseline conditions. For both NO and NO$_2$, stronger reductions were observed, −88.1% and −68.9% in Nice, −70.5% and −55.1% in Rome, and −75.5%, and −70.6% in Valencia, respectively. Furthermore, PM$_{10}$ concentrations decreased during the lockdown by 5.9% in Nice, 8.9% in Turin, 32.1% in Valencia, and 48.7% in Wuhan, while PM$_{10}$, surprisingly, slightly
increased 1.8% in Rome. Regarding PM$_{2.5}$, it was changed by $-2.9\%$, $+10.6\%$, $-12.6\%$, $-12.6\%$ and $-36.3\%$ in Nice, Rome, Turin, Valencia, and Wuhan, respectively (Sicard et al., 2020).

NO$_2$ emissions in the lockdown environment have decreased by around 30% in China and by 25% in Japan (Liu et al., 2020). In the main cities of the world, where the COVID 19 epidemic was large, Cadotte (Cadotte) observed a reduction in air contaminants. The close correlation between NO$_2$ concentration and the fatal COVID-19 outcome was established by Ogen (2020). Likewise, Coccia (2020) found a clear correlation between air pollutants, especially PM$_{10}$ and ozone, to accelerate and spread COVID-19 in the northern Italian capital cities (Mahato et al., 2020).

4.9. General findings

It was suggested by El Zowalaty et al. (El Zowalaty et al., 2020) that many lessons could be learned from the COVID-19 crisis. For instance, some activities could be done at home, such as teleconferencing, work, studying, etc., which could help in reducing traveling and thus fuel emissions. Also, due to the improvement in air quality, it gave a conception of the huge impact of fossil fuel on air quality and the future aspects of fuel usage.

Similarly, Roman-Gonzalez and Vargas-Cuentas (2020) studied the air quality in Peru using data that was collected by the European Space Agency (particularly, Sentinel-5 Precursor satellite). A decrease in the aerosol contaminations was noticed in multiple areas in Peru, essentially in the Amazon and Lima zones. During the first ten days of the quarantine, a noticeable reduction in air pollution was obtained. As the lockdown went farther, the air quality improved higher. Studying the gases and other pollutants separately and finding relationships connecting them could be good topics to investigate.

In a general view, Rosenbloom et al. reported the effect of the COVID-19 pandemic on human lives and climate changes. The pandemic intensifies the health system and social life directly, while the positive impact on the climate has appeared. Hence, there was a reduction in air pollution and global warming, which was attributed to the lower transportation and manufacturing processes closure. This improvement in climate may lead to the use of new infrastructures, such as the renewable energy forms of solar and wind energy and the use of electric vehicles for transportation. The recovery program of COVID-19 was able to design new bases and strategies to use sustainable energy for a flourishing life in the future (Rosenbloom and Markard, 2020).

Opinions of doctors and researchers about the responding actions by people toward the pandemic were reported. A sudden change in people’s behavior was noticed in order to deal with COVID-19, where the use of cleaners and detergents led the poison center to receive calls up to 20% more than before COVID-19. Because of the resulted outbreak and quarantine, people were forced to stay home, and transportation was significantly reduced. This resulted in a decrease in air pollution but influenced the psychological situation of people. Yet, a clear reduction in air pollution was reported by NASA satellites around the world. Hence, Marshall Burke, an environmental economist at Stanford University, concluded that the improvement in air quality in China might rescue the lives of 4 thousand children <5 years and 73 thousand adults <70 years. A similar situation can be obtained in the US. Burke quoted, “A pandemic is a terrible way to improve environmental health” (Nelson, 2020).

COVID-19 could transfer within the indoor air circulation system, which gives an additional reason for the infection. Hence, Ren et al. suggested disinfecting the indoor places’ air, such as hospitals, clinics, malls, etc., by using an ultraviolet circulating system to get extra protection. This could help since patients’ bodies, clothing, and stuff are contaminated with the virus (Ren et al., 2020). The use of ultraviolet rays (254 nm UV-C) has successfully deactivated the aerosols of coronavirus (Walker and Ko, 2007). However, classic ultraviolet radiation systems could cause eyes and skin burn, so it is not easy to disinfect the air during people’s presence. Here, the high radiation ultraviolet system produces an air of the best disinfection quality. This way is considered suitable for indoor locations with high transportability (Ren et al., 2020).

5. Conclusion

In this review, we showed that the COVID-19 pandemic highly affected air quality, particularly in large countries. The levels of NO$_x$, PM$_{2.5}$, PM$_{10}$, CO, etc. extremely decreased after the lockdown, where the industrial countries stopped their production lines, and their employees started working from home. From the reviewed studies, it can conclude that there is a direct relation between air pollution and COVID-19 mortality rates. The pollutants reduce the lung’s health and cause an overexpression in the ACE-2, which increases SARS-CoV-2 reception. This results in serious conditions in the patient and could cause death. Many lessons could be learned from the COVID-19 pandemic, which needs to be considered in the future. For example, regardless of the fast development that humanity conducts, nature is still much stronger than us. The misuse of exploitation of nature’s resources leads to bad outcomes that could threaten humanity as in the COVID-19 case. Culturing people about the rules and how to obey the emergency plans is important to avoid the undesired consequences. More medical checks and health care treatments are required for those who work in highly polluted areas and unhealthy environments. Work, study, and any other activities that can be done online are encouraged to be conducted home, instead of having people mixing and fuel-burning to arrive office and perform the same required duties. Finally, we should take care of our planet because we have nowhere else to live at; planet earth’s health means our health.

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