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## Positive environmental effects of the coronavirus 2020 episode: a review

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### Abstract

The outbreak of COVID-19 has made a global catastrophic situation that caused 1,039,406 deaths out of 35,347,404 infections, and it will also cause significant socio-economic losses with poverty increasing from 17.1 to 25.9%. Although the spreading rate of COVID-19 is very high on October 6, 2020, the death rate is still less than 2.94%. Nonetheless, this review article shows that the lockdown has induced numerous positive impacts on the environment and on energy consumption. For instance, the lockdown has decreased the electricity demand by 30% in Italy, India, Germany, and the USA, and by 12–20% in France, Germany, Spain, India, and the UK. Additionally, the expenditure of the fuel supply has been decreased by 4% in 2020 as compared to the previous years (2012–2019). In particular, The global demand for coal fuel has been reduced by 8% in March and April 2020 as compared to the same time in 2019. In terms of harmful emissions, the lockdowns reduced the emissions of nitrous oxides by 20–30% in China, Italy, France, Spain, and by 77.3% in São Paulo, Brazil. Similarly, the particulate matter level has been reduced from 5–15% in Western Europe, to 200% in New Delhi, India, which in turn has enhanced the air quality in a never-seen manner in recent times. In some places, such as New York, USA, CO<sub>2</sub> emission was also reduced by 5–10%. The water quality, in several polluted areas, has also been remarkably enhanced, for example, the dissolved oxygen content in the Ganga River, India, has increased by about 80%. Traffic congestion has also been reduced worldwide, and in some areas, it has been reduced by 50%, such as New York and Los Angeles, USA. Overall, while the COVID-19 pandemic has shrunk the global economy by 13–32%, the pandemic has also clearly benefited to other sectors, which must be considered as the spotlight for the permanent revival of the global ecosystem.

**Keywords** COVID-19 benefits · Environmental regeneration · Renewable energy · Air pollution · Surface water · Traffic congestion

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Co-first author, Milad Mousazadeh and Biswaranjan Paital contributed equally to this work.

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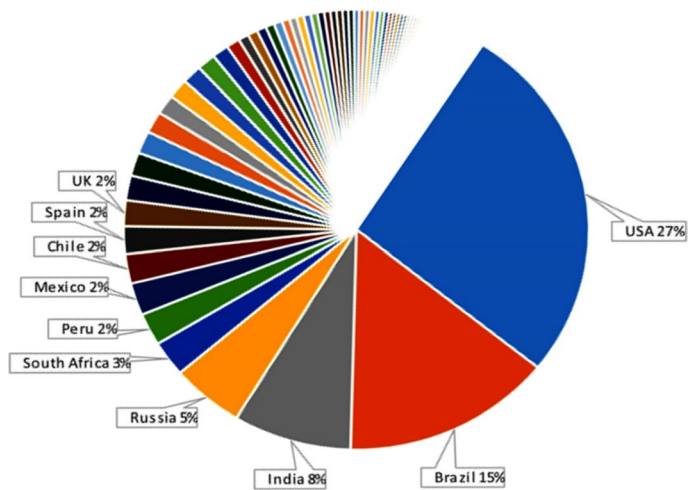
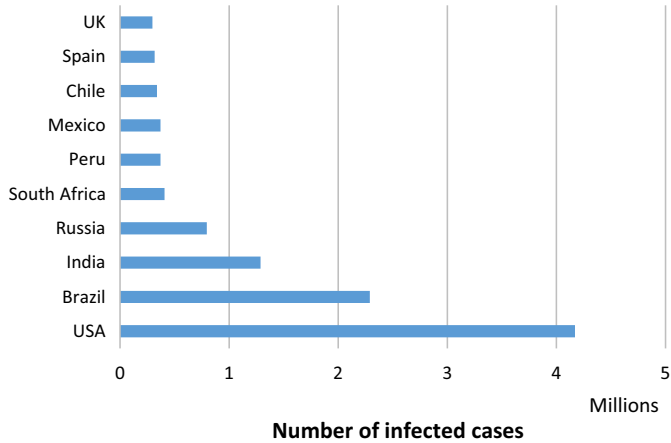
# 1 Introduction

A novel respiratory infection caused by a virus belonging to the coronavirus family was identified in Wuhan city, China, in late December 2019. The corresponding disease became known as the coronavirus disease or COVID-19 (CDC 2020; Muhammad et al. 2020; WHO 2020b). The viral infection has then rapidly spread across the globe, and was declared as a public health emergency of international concern by the world health organization on January 30, 2020 (Chakraborty and Maity 2020; WHO 2020c). COVID-19 has generated unprecedented impacts in 216 countries. As of July 24, 2020, rolling data indicate that 15,666,840 people have been infected by the disease, from which 636,789 have died and 9,554,890 recovered (Fig. 1; Paital 2020; Worldometers 2020).

Major international and domestic flights have been cancelled, transport systems including railway services, bus, truck and vehicle transport have been suspended, except goods trains and emergency vehicles. Educational, commercial, sports and spiritual institutions were closed, social gatherings were restricted, and citizens were advised to stay at home. Power plants, manufacturing and industrial facilities halted production, except those related to essential services (Chakraborty and Maity 2020; Paital 2020; Saadat et al. 2020; Zambrano-Monserrate et al. 2020). These containment measures induced a sharp drop in social, industrial, and economic activities. Nonetheless, lockdown also induced a strong reduction in air pollution due to the massive decrease in the combustion of fossil fuels and, more generally, energy consumption (Zambrano-Monserrate et al. 2020). For instance, decreases in emissions of greenhouse gases such as nitrogen dioxide ( $\text{NO}_2$ ), sulfur dioxide ( $\text{SO}_2$ ), and carbon dioxide ( $\text{CO}_2$ ) were observed, and  $\text{CO}_2$  emissions fell by 18% during February and March 2020 in China (Paital 2020; Wang and Su 2020; Zambrano-Monserrate et al. 2020).

Public mobility diminished by up to 90% as a result of lockdown policies, including traffic restrictions and people staying at home. For instance, passenger vehicle traffic in the USA reduced by 40%. With less human activity, noise levels dropped in many cities around the world (Muhammad et al. 2020; Paital 2020; Zambrano-Monserrate et al. 2020). Social distancing policies have kept people from resorts and beaches around the world while industrial shutdown has paused effluent discharge into water bodies. Such events resulted in water quality improvement due to less pollution observed in different countries such as Mexico, Spain and Ecuador. For example, Venice's canals and the Yamuna river in Delhi, India, is now significantly clearer compared to the past (Paital et al. 2020; Saadat et al. 2020). However, the above positive effects of the COVID-19 pandemic should not be seen as long-term ways to control environmental pollution because this pandemic should stop within a relatively short period of time and global social and economic activities should return to their normal level. Thus, these short-term positive impacts of COVID-19 should be utilized to develop effective future policies to protect the environment (Allegrante et al. 2020; Chang et al. 2020; Espejo et al. 2020; Ferguson et al. 2020; Raoofi et al. 2020). These policies must take into account the potential impacts of the massive re-opening of industries after the COVID-19 pandemic to cover the loss during lockdowns, which could result in a rapid increase in environmental pollution.

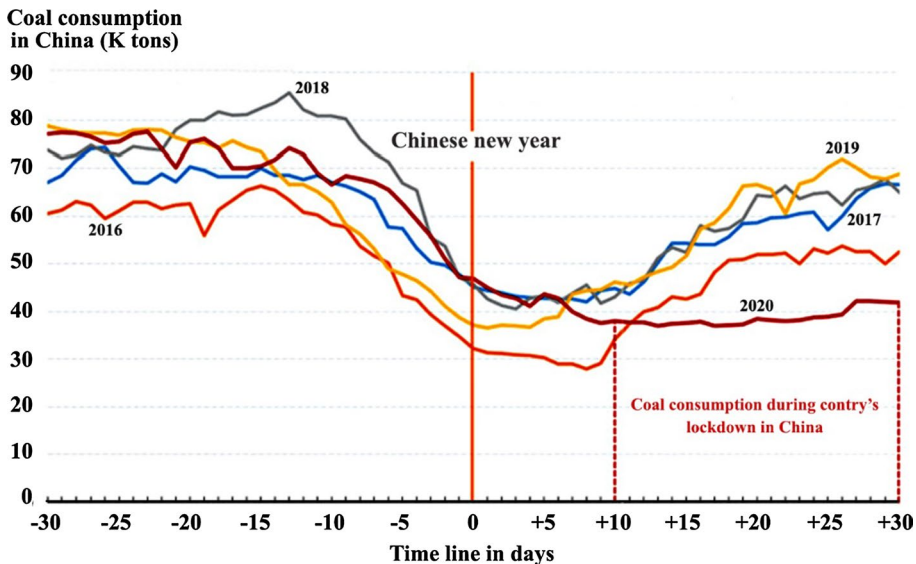
Otherwise, the world has to wait for another pandemic to minimize the environmental pollution. In this context, we analyzed the scientific literature along with news sources, such as Science magazine, Reuters, BBC News, Times, Hindustan India, India Today, WHO, to uncover the lessons of the lockdowns.



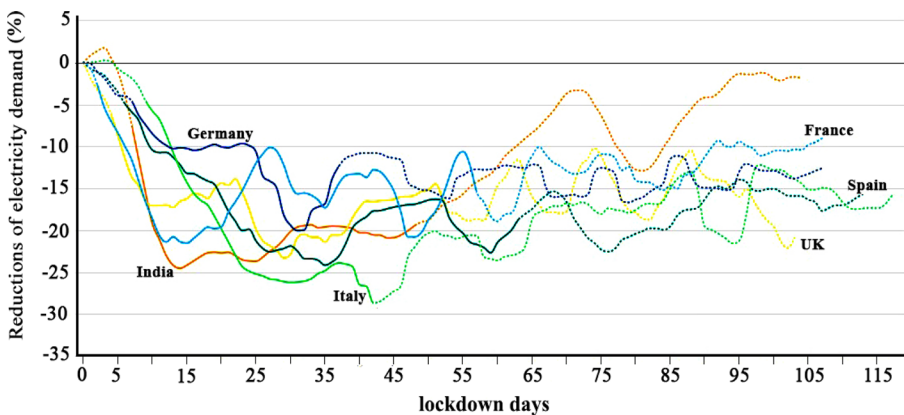
**Fig. 1** Total number of coronavirus disease 2019 cases in the major affected countries as of July 24, 2020. The report shows total infected cases for 10 hardest-hit countries worldwide including 4,170,131 (27%) cases in the USA, 2,289,951 (15%) cases in Brazil, 1,290,284 (8%) cases in India, 800,849 (5%) cases in Russia, 408,052 (3%) cases in South Africa, 371,096 (2%) cases in Peru, 370,712 (2%) cases in Mexico, 338,759 (2%) cases in Chile, 317,246 (2%) cases in Spain, and 297,146 (2%) cases in United Kingdom (Worldometers 2020)

## 2 Energy

A substantial decline in energy was observed in countries that followed complete or partial lockdown (Figs. 2 and 3). Specifically, this was caused by total lockdown in India, the USA, China and Italy, where all industries were closed during the first and second phases of lockdown (Cohen 2020; IEA 2020). For example, electricity consumption declined to almost 30% in Italy after 40 days of lockdown. Similarly, electricity consumption declined by 15% in France, 12% in Germany, 15% in Spain, 20% in India, and 16% in the UK. Overall, electricity demand during COVID-19 was at least 10% lower in comparison to pre-COVID-19 times.



**Fig. 2** Use of coal fuel in China in 2016–2020. The consumption drop for all years during the Chinese new year is explained by holidays with industrial shutdowns. In 2020 coal consumption is drastically reduced to 40 K tons during the lockdown, 10–30 days after the new year, versus about 80 K tons before the COVID episode (Ghosh 2020)



**Fig. 3** The decline in electricity during COVID-19 lockdown. Dotted lines show partial lockdown, solid lines display full lockdown. Up to 30% reduction in electricity consumption is observed in Italy after 40 days of lockdown. About 15, 12, 15, 20, and 16% reduction in electricity consumption are observed in France, Germany, Spain, India and the UK, respectively. The transition from full to partial lockdown induced a rise, but the electricity consumption still remained 10% lower than that of pre-COVID times. Modified after IEA (2020)

Energy reduction is explained by lockdowns (Fig. 3). Whereas 5–50% higher energy consumption has been observed in hospitals from 216 affected nations from mid-March 2020 to mid-April 2020, energy consumption has decreased in other sectors. Indeed, a reduction of about 25% on the average in weekly energy consumption has

**Table 1** Global energy investment from 2017 to 2020

Year	Expenditure in fuel supply (USD billions)	Power Sector	Energy end-use and efficiency
2017	850	782	280
2018	854	769	281
2019	854	757	280
2020	<b>595</b>	<b>678</b>	<b>247</b>

A sharp decrease is observed in 2020 during the COVID episode. Expenditures are approximate, data in 2019 USD billions. Modified after IEA (2020)

been noticed in 30 fully locked down nations up to mid-April 2020. This energy reduction was nearly 18% in partially locked down countries (Sarkar 2020; SEI 2020). In the same vein, global energy expenses decreased by 40% compared to previous years (Table 1). This indicates a stringent reduction in energy consumption. For example, in India where lockdown was implemented quite stringently, peak power demand dropped to 134.89 gigawatts in 2020 as compared to 168.62 gigawatts in 2019, registering a drop of 20%. Electric energy demand was reduced by 30% nationwide in COVID-19 induced lockdown time as compared to the pre-COVID-19 time (Sarkar 2020).

A similar trend was also observed for coal consumption. The global demand for coal reduced at least by 8% in March and April 2020 lockdown periods compared to the same time period in 2019. China, a country responsible for 6% of global fossil fuel emissions, experienced a drastic reduction in coal consumption in the first quarter of 2020, of 36% compared to 2019 (Ghosh 2020; Wang and Su 2020). In absolute amounts, this translates into a reduction from 80 to 40 K tons of burned coal (Paital 2020; Paital et al. 2020). Similarly, global oil consumption was reduced by 5% in the first quarter during the lockdown, in Europe, North America, and allied countries. Global gas consumption also declined by 2% during the same period (Sarkar 2020; SEI 2020).

Under such a global crisis against COVID-19, the potential use of renewable energy has been emphasized because household electricity consumption would be elevated at lockdown timings. The use of renewable energy sources over conventional energy resources is another positive effect observed during the COVID-19 period (Hosseini 2020). Large scale use of solar panels and windmills for both household and industrial sectors have been suggested. (Destouni and Frank 2010; Ergun et al. 2019; Li et al. 2019) Such steps at COVID-19 period would lead to establishing a foundation leading to a cleaner as well as a sustainable new epoch in the energy sector.

The consumption of both fossil fuel and electrical energy has been dramatically reduced in the industry, public offices, educational sectors, and private organizations (Table 1). The global expenditure on energy consumption remained almost the same in the years 2017, 2018 and 2019. The global expenditures in fuel supply and energy end-use in 2019 was not significantly different from previous years (about 5% lower). However, expenditure decreased slightly (about 15%) from 2019 to 2020 for power sectors and energy end-users. On the other hand, expenditure in fuel supply drastically reduced to almost 30% in 2020 compared to previous year because of COVID-19 induced lockdowns (IEA 2020).

### 3 Air pollution quality

Air pollutants such as NO<sub>2</sub>, SO<sub>2</sub>, O<sub>3</sub>, CO and particulate matter (PM) pose serious health risks (Paital and Agrawal 2020). The WHO estimates that 7 million people die from air pollution each year, more than half these deaths being due to ambient air pollution (WHO 2020a). Long-standing exposure to fine PM with a diameter lower than 2.5 μm, and O<sub>3</sub>, is estimated to cause around 8.8 million deaths every year (Lelieveld et al. 2020). Exposure to NO<sub>2</sub> alone results in 4 million new pediatric asthma cases annually (Achakulwisut et al. 2019).

A major and immediate positive effect of COVID-19 lockdown has been the substantial reduction in air pollution worldwide, notably in major industrialized countries (Table 2). The closure of factories and transportation networks, the largest emitter of greenhouse gases in the United States, resulted in a 5–10% decrease in air pollutants, including CO<sub>2</sub> (Chelsea Harvey 2020; McGrath 2020). China's heavy industrial zones also showed a 40% reduction in NO<sub>2</sub> concentrations after the lockdown in Wuhan (Wang and Su 2020).

Estimations from the ESA's Sentinel-5P satellite confirm that during late January and early February 2020, levels of NO<sub>2</sub>, a well-known pollutant emitted by road transportation, over big cities and industrial zones in many Asian and European countries, were reduced by as much as 40% in comparison with the similar periods in 2019 (Monks 2020). Bauwens et al. (2020) evaluated the effect of the coronavirus outbreak on changes in NO<sub>2</sub> level over the major epicenters in China, South Korea, Italy, Spain, France, Germany, Iran and the United States by satellite measurements of air quality. They found that emissions declined in all countries by 20–40%. Nonetheless, in Iran, one of the earliest and hardest-hit countries, there was no observed drop in NO<sub>2</sub> emissions. This is probably due to no complete lockdowns until the end of March, during the Iranian New Year holidays, and, before that, stay-at-home orders were largely ignored.

With worldwide financial action slowing down as a result of the coronavirus episode, it is not surprising that emissions related to energy and transport would be diminished (McGrath 2020). Satellite image data of more than 10,000 air quality measurement stations in 27 countries indicate a reduction in ground level NO<sub>2</sub> by 29% with a 95% confidence interval. Similarly, concentrations of ground level O<sub>3</sub> were reduced by 11%. Moreover, the PM<sub>2.5</sub> value decreased by 9% during the initial 14 days of lockdowns (Venter et al. 2020). NASA and ESA data showed that the amount of particles and NO<sub>2</sub> had dropped significantly over China. For instance, PM<sub>2.5</sub> levels fell by 25%, and NO<sub>2</sub>, created primarily by diesel vehicles, dropped by 40% in Wuhan (Leung 2020). NO<sub>2</sub> levels in China, USA, Europe, and India before and during lockdown are shown in Figs. 4, 5 and 6. Accordingly, NO<sub>2</sub> emissions declined by 20–30% in China, Italy, France, and Spain, by 30% in the USA, and by 40–50% in India during lockdown periods.

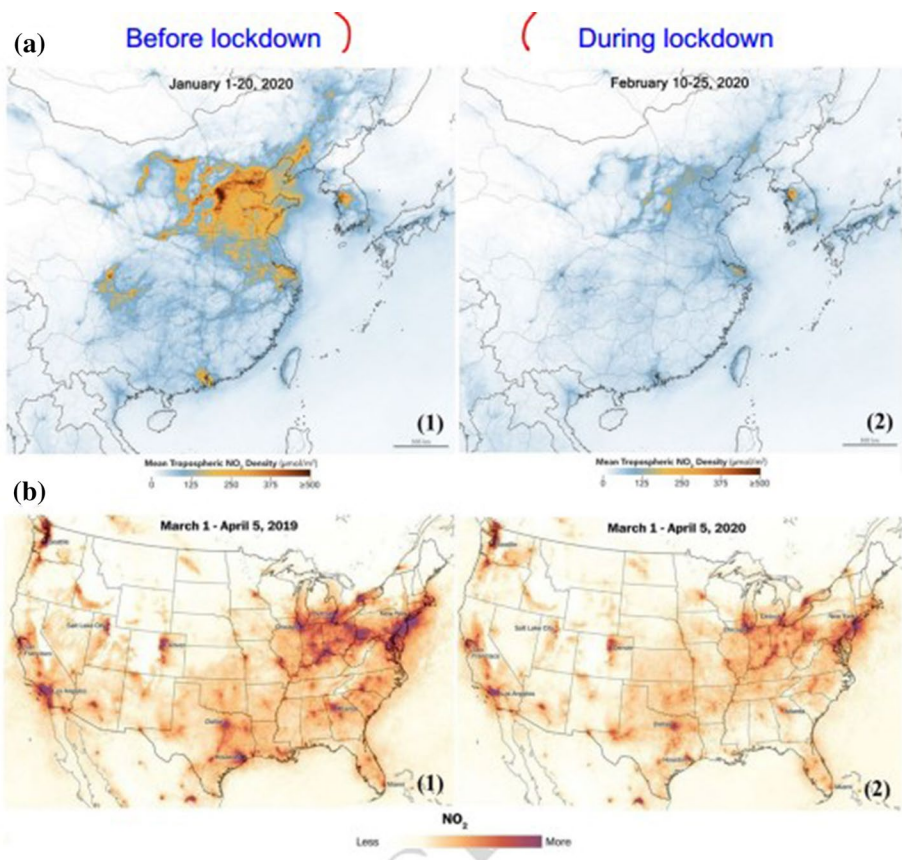
Evidence suggests that the COVID-19 outbreak has resulted in global environmental changes which can be attributed to the complete or partial lockdown of cities worldwide (Chakraborty and Maity 2020). For instance, Le Quéré et al. (2020) analyzed global CO<sub>2</sub> emissions from 69 countries, 50 US states, and 30 Chinese provinces, including 85% of the world's population and 97% of global CO<sub>2</sub> emissions, compared to time pre-COVID-19. In early April 2020, compared to the same period in 2019, they found that daily global CO<sub>2</sub> emissions decreased by 17% on the average (Fig. 7). Some countries showed a decrease up to 26%. The study also predicted that if lockdown restrictions would continue, an annual global emissions decline of up to 7% could be achieved. In other words, lockdown was efficient to offset global warming.

**Table 2** The decline of major air pollutants in early 2020 compared to 2019, and main causes

Country	Major pollutants reduction	Major causes	References
27 countries	NO <sub>2</sub> 13–44% O <sub>3</sub> 2–20% PM <sub>2.5</sub> 10–28% CO <sub>2</sub> 5–10% NO <sub>2</sub> 20–30% NO <sub>2</sub> 30% NO <sub>2</sub> 40–50% PM <sub>2.5</sub> 200% PM <sub>10</sub>	Closure of factories, transportation networks, and companies	Venter et al. (2020)
New York (USA)	PM <sub>2.5</sub> 10–28% CO <sub>2</sub> 5–10%	Closure of factories, transportation networks, and companies	McGrath (2020)
China, Italy, France, and Spain	NO <sub>2</sub> 20–30% NO <sub>2</sub> 30%	Closure of factories, transportation networks, and companies	Leung (2020)
USA	NO <sub>2</sub> 30%		
India	NO <sub>2</sub> 40–50%		
Delhi (India)	PM <sub>2.5</sub> 200% PM <sub>10</sub>	Restricted travel including flights, rail, intercity bus services and industrial activity stopped	Kotnala et al. (2020)
Western Europe	NO <sub>2</sub> 30–50% PM 5–15%	–	Menut et al. (2020)
São Paulo (Brazil)	CO 64.8% NO 77.3% NO <sub>2</sub> 54.3%	Closure of shopping malls, restaurants, fitness centers, schools, universities, and public transportation restrictions	Nakada and Urban (2020)
Barcelona, Madrid (Spain)	NO <sub>2</sub> 50% 62%	Decreases in vehicular mobility and the volume of other relevant activities such as port and airport operations	Baldasano (2020)
Rio de Janeiro (Brazil)	CO 30.3–48.5% NO <sub>2</sub> 16.8–53.8% NO <sub>x</sub> 24.4–46.1%	Vehicle circulation restrictions, suspension of classes, and many other activities	Dantas et al. (2019), Siciliano et al. (2020)
Wuhan (China)	PM <sub>2.5</sub> 25% NO <sub>2</sub> 40%	– Use of diesel vehicles stopped	Leung (2020)

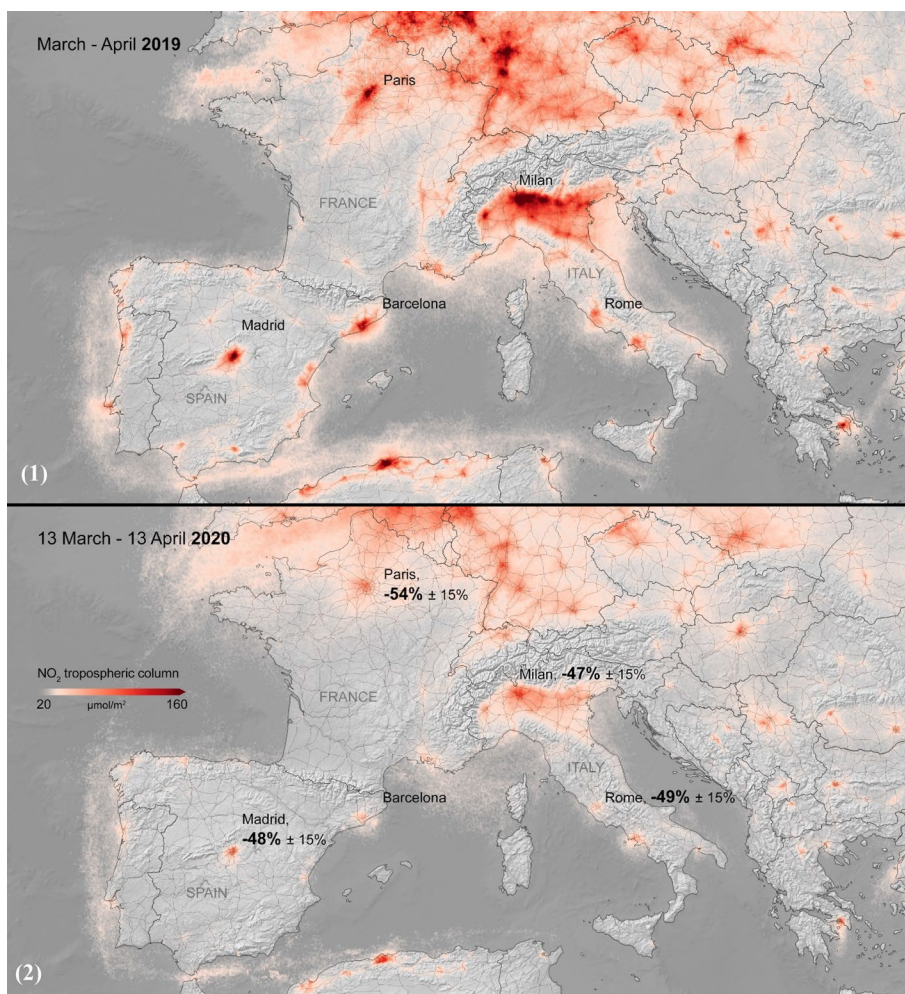
For instance, Wuhan city, the primary epicenters of the outbreak, has reduced NO<sub>2</sub> by about 40%. Similarly, observations in the USA and India showed a 30–50% reduction





**Fig. 4** Nitrogen dioxide levels in China, before and during lockdown and in the USA, in 2019 and 2020. In China, NO<sub>2</sub> declined initially reduction near Wuhan and then rapidly over the whole country. Credit: (NASA 2020b)

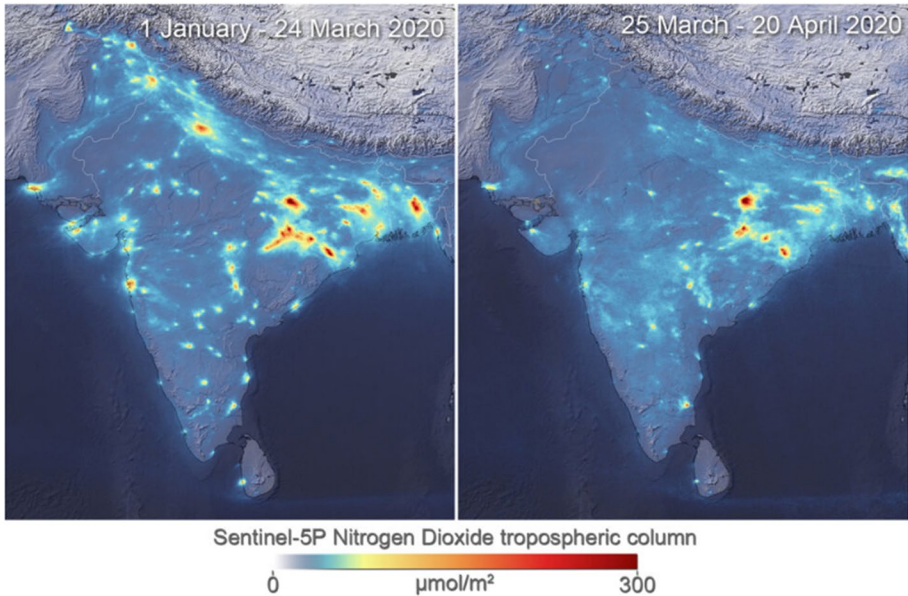
A recent study of the impact of COVID-19 lockdown measures revealed amplified average daily ozone concentrations at various urban stations (Sicard et al. 2020). There were ozone increases of 24% in Nice, 14% in Rome, 27% in Turin, 2.4% in Valencia and 36% in Wuhan compared to the same period in 2017–2019. This increase in O<sub>3</sub> concentration is mainly due to the decrease in NO<sub>x</sub> because at ground level ozone is created by reactions between NO<sub>x</sub> and volatile organic compounds (VOC). A study also found that O<sub>3</sub> production during lockdown was higher during weekends (Sicard et al. 2020). Similar increases of O<sub>3</sub> concentrations were also observed: 20% in Sao Paulo (Nakada and Urban 2020), 50% in Barcelona (Tobías et al. 2020), 11% in London (Authority 2020), 17% in 22 Indian cities (Sharma et al. 2020), 116% in Wuhan (Lian et al. 2020), 43% in Beijing-Tianjin-Hebei region (Le et al. 2020) and 15% in Almaty (Kerimray et al. 2020). Overall, most air pollutants declined strongly during the COVID episode, with the exception of ozone, which increased notably. As a consequence, and contrary to the common belief, these findings show that decreasing air pollution and offsetting global warming is feasible in a short time period. This of course has caused negative



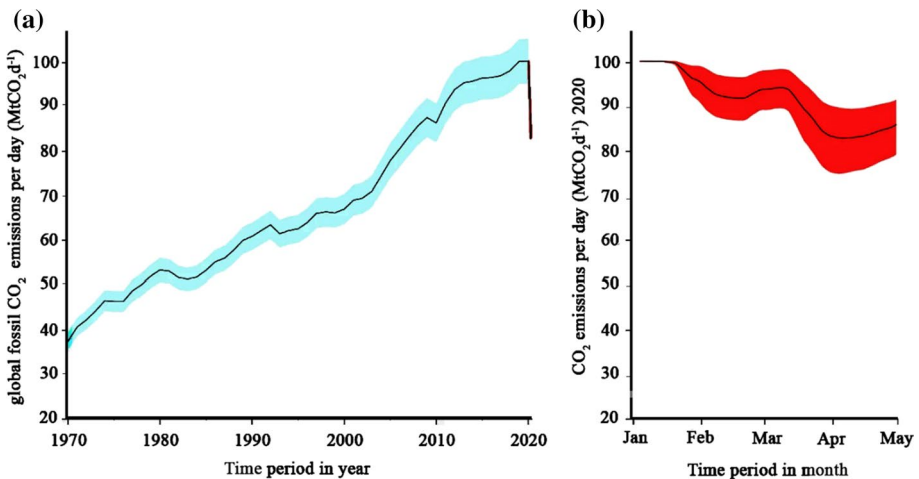
**Fig. 5** Nitrogen dioxide levels in European countries before (up) and during the lockdown. The mean nitrogen dioxide content in Madrid, Milan and Rome decreased by about 45%, and by 54% in Paris, compared to 2019. From Copernicus Sentinel data 2019–2020 processed by KNMI/ESA (ESA 2020a)

consequences for the economy, but findings are inspiring to find solutions for a more sustainable society.

To date, although little data is available, emerging evidence suggests that there may be a positive association between prolonged exposure to air pollution and the death of COVID-19. There is previous evidence from previous coronaviruses, e.g. SARS-CoV-1, that people exposed to polluted air were at higher risk of death. Accordingly, researchers found that people in areas with more air pollution were twice as likely to be infected as people in areas with less pollution (Cui et al. 2003). In the case of the SARS-CoV-2 virus pandemic, few studies have been investigated on the association between clean air and the reduction in death rates due to COVID-19. Wu et al. (2020) found that an increase of only  $1 \mu\text{g}/\text{m}^3$  in long-term exposure to  $\text{PM}_{2.5}$  was associated with a 15% increase in the risk of COVID-19 mortality. As of March 19, 2020, Ogen (2020) observed that 4443 deaths of COVID-19



**Fig. 6** Nitrogen dioxide levels before (left) and during the lockdown in India in 2020.  $\text{NO}_2$  mean levels decreased by about 40–50% from the January 1–March 24 periods to the March 25–April 20 period. Noteworthy, high  $\text{NO}_2$  concentrations coincide with the location of power plants. Modified from Copernicus Sentinel data (2019–20), processed by ESA, CC BY-SA 3.0 IGO (ESA 2020c)



**Fig. 7** Fossil fuel  $\text{CO}_2$  emissions ( $\text{MtCO}_2 \text{d}^{-1}$ ) for the 1970–2019 timeline compared to during the COVID-19 confinement period (2020). Blue shading showing annual  $\text{CO}_2$  emissions from 1970 to 2019 (a).  $\text{CO}_2$  emissions have been nearly upward trend every year, with about  $100 \text{ MtCO}_2 \text{d}^{-1}$  being released in late 2019. Conversely, since early 2020, red shading shows a significant decrease in carbon emissions during confinement (b). On April 7, 2020, the influence of the confinement on daily global  $\text{CO}_2$  emissions was around  $-17 \text{ MtCO}_2 \text{d}^{-1}$  ( $-17\%$ ) in contrast to the average level of emissions in 2019. Also, during January–April 2020,  $\text{CO}_2$  emissions fell by  $1.048 \text{ MtCO}_2 \text{d}^{-1}$  ( $8.6\%$ ) compared to 2019 levels. Modified after Le Quééré et al. (2020)

occurred in 66 regions of France, Germany, Italy, and Spain. Analyzing NO<sub>2</sub> concentration data from the Sentinel-5 Precursor space-borne satellite, they reported that 83% of these deaths occurred in areas with the highest NO<sub>2</sub> concentration and only 1.5% in areas with the lowest NO<sub>2</sub> concentration.

Research shows that prolonged exposure to air pollution causes chronic inflammation and an increased risk of chronic respiratory disease, both of which are associated with an increased risk of death in COVID-19. Evidence in northern Italy proves this point (Contini et al. 2020). Cocker et al. (2020) also showed that an increase in a unit concentration of PM<sub>2.5</sub> was associated with a 9% increase in COVID-19 mortality. Liang et al. (2020) also found in the US states that urban air pollution may increase the COVID-19 mortality rates. With the increase of the per inter-quartile range (4.6 ppb) in NO<sub>2</sub>, COVID-19 case rate and death rate increased by 11.3% and 16.2%, respectively. There was also a 15% increase in COVID-19 mortality for the increase in the per inter-quartile range in PM<sub>2.5</sub> (2.6 ug/m<sup>3</sup>). In another study in Ghana, there was no link between home air pollution and acute lower respiratory tract infections caused by the COVID-19 (Carrión et al. 2019).

Although it is not yet certain that interventions to improve air quality will reduce the severity of COVID-19 disease, it cannot be ignored. Therefore, we should do our best to improve air quality because it should have significant impact on reducing the basic demand for health services during the COVID outbreak. Information, in general, is limited and robust research is needed on the level of air pollution and the potential link to COVID-19, which could improve public health policy in this regard.

#### **4 Surface water quality and wastewater surveillance**

The COVID-19 pandemic has had beneficiary consequences on surface water quality in some regions as lockdown has improved the water quality of some rivers, canals and seas (Table 3). One of the positive impacts of COVID-19 (Fig. 8) according to satellite images is that Venice's canals became clearer after one month of lockdown (ESA 2020b). Niroumand-Jadidi et al. (2020) reported an almost 50% reduction in total suspended matter (TSM) after lockdown using shallow-water inversion via Planet Scope imagery. Before the COVID-19 periods, the concentration of TSM was 3 g/m<sup>3</sup> on average; however, it was reduced to 1.4 g/m<sup>3</sup> during COVID-19 lockdown. Because of a reduction in boat traffic, sediments have settled resulting in a reduction in turbidity. Banning tourists during lockdown has also reduced water pollutants released by tourists. This clearer water has enabled other creatures such as fish, dolphins and swans to come back to these canals and waterways. Beaches, including Acapulco (Mexico), Barcelona (Spain), and Salinas (Ecuador) have had crystal clear waters since the reduction in tourists (Zambrano-Monserrate et al. 2020).

The other advantage of nationwide lockdown is the improvement of the water quality in some Indian rivers which are normally exposed to polluted industrial and human effluents (Lokhandwala and Gautam 2020). For example, the River Cauvery had been polluted by wastewater discharge from homes and resorts on the banks of the river, but the lack of tourists has reduced wastewater discharge keeping the water quality in the "A" category since lockdown (DeccanHerald 2020). Garg et al. (2020) analyzed the turbidity level along the Ganga river and its stretches including Haridwar, Kanpur, Prayagraj, and Varanasi using remote sensing data; the reduction in reflectance in the visible and near infrared (NIR) region of Sentinel-2A/B data indicated the turbidity reduction.

**Table 3** Surface water quality enhancements around the world during the lockdown

Country	Water resources	Major reasons for pollution reduction	References
Ecuador	Salinas Beach	Tourist reduction	Zambrano-Monserrate et al. (2020)
India	Vembanad Lake	Tourism reduction, Reduction in industrial effluents	Yunus et al. (2020)
	River Cauvery	Tourist reduction, Less human activity	DeccanHerald (2020)
	Ganga River	Reduction in industrial effluents, Reduction in water lifting by industries, Tourist reduction	Singhal and Matto (2020)
	Yamuna River	Reduction in industrial effluents, Reduction in water lifting by industries	Paital et al. (2020)
Italy	Venice's Canals	Boat traffic reduction, Tourist reduction	Zambrano-Monserrate et al. (2020)
Mexico	Acapulco Beach	Tourist reduction	Zambrano-Monserrate et al. (2020)
Peru	Rimac River	Reduction in dumping garbage, construction materials or waste from businesses and industrial sectors	Newsweek (2020)
Spain	Barcelona Beach	Tourist reduction	Zambrano-Monserrate et al. (2020)

Water resources (e.g., beach and lake) in different countries, including, Ecuador, India, Italy, Mexico, Peru, and Spain and major causes (e.g., tourist reduction and less human activities) of these improvements are listed separately. Based on on-site observation and remote sensing analysis, the water in the canals looks clearer due to the limited movement of boats, fewer tourists, etc., as the spread of the coronavirus and stay at home orders

According to the Centre Pollution Control Board's (CPCB) real-time water quality monitoring data on April 19, the pre-COVID polluted Ganga river has met drinking water standards, with biological oxygen demand level lower than 3 mg/L, dissolved oxygen (DO) greater than 4 mg·L<sup>-1</sup>, and pH=6–8, in a manner never seen before. After a month lockdown, DO level was improved by 79%. Although more than 80% of pollution in the Ganga River is related to domestic sewage, which has increased during the COVID-19 pandemic, the lack of other sources of pollution, such as industrial effluents and tourism activities, have increased the water quality. Aside from the reduction in industrial effluent, water lifting by industries has also decreased, resulting in a dilution of pollutants in the river (Singhal and Matto 2020).

Because of lockdown and industrial shutdown in New Delhi, India, the quality of water in the Yamuna River has improved more than fivefold downstream according to a CPCB report (Paital et al. 2020). The mix of detergents and chemicals from industries and sewage produced toxic foam in southeast Delhi's Kalindi Kunj disappeared during the lockdown (Lokhandwala and Gautam 2020). The highly polluted Rimac River in Peru, which is the main water supply for the capital, Lima, also has experienced improvements in water quality since the lockdown. According to Peru's National Water Authority, because the dumping of garbage, construction materials and waste from businesses and industrial sectors has stopped, this has improved water quality. The volume of solid waste in the La Atarjea water treatment plant has been reduced by 90%; this was also beneficial for the treatment plant (Newsweek 2020). As a result, less human activity, a reduction in tourism and the reduction in industrial effluents, has led to improvements in water quality in some regions of the world. These quality improvements resulting in transparent waters, also allowed



**Fig. 8** Venice lagoons and waterways quality (top) in 2020 and (bottom) after a month pandemic lockdown in 2019. Due to lockdown in Venice, Italy's canals, on March 2020, boats traffic (e.g., water buses) dramatically decreased, which prevents reaching the sediments to the top of the water's surface, making the canal's water look cleaner. As the top image shows, captured April 13, 2020, the traffic appears almost empty in the Grand Canal compared to the same time last year. Credit: Copernicus Sentinel data (2019–20)/ESA, CC BY-SA 3.0 IGO (ESA 2020b)

wildlife to find a chance to be free from pollution. Sadly, such environmental effects will be temporary.

Coronavirus may affect the produced wastewater of a community, which would be an opportunity for decision-makers to adopt proper strategies by monitoring the wastewater. Ahmed et al. (2020) detected SARS-CoV-2 in untreated wastewater of Australia using reverse transcription-quantitative polymerase chain reaction (RT-qPCR) assay which confirms the necessity of wastewater-based epidemiology (WBE) (Sharma et al. 2021). Considering the potential role of wastewater in the SARS-CoV-2 transmission, Kitajima et al. (2020) indicated that researches should be conducted to reveal knowledge on the survival and stability of this novel coronavirus in aquatic media; in this regard, wastewater surveillance plays a crucial role in providing useful data to possibly distinguish undiagnosed or successive disease in the community; WBE surveillance tool could provide precaution signs on how broadly the virus is circulating in the community. Hart and Halden (2020) conducted a computational modeling study and cost analysis survey to confirm the effectiveness of WBE in tracking COVID-19; they suggested that this tool requires to consider the temperature effects as well. Sharif et al. (2020) also applied the existing polio

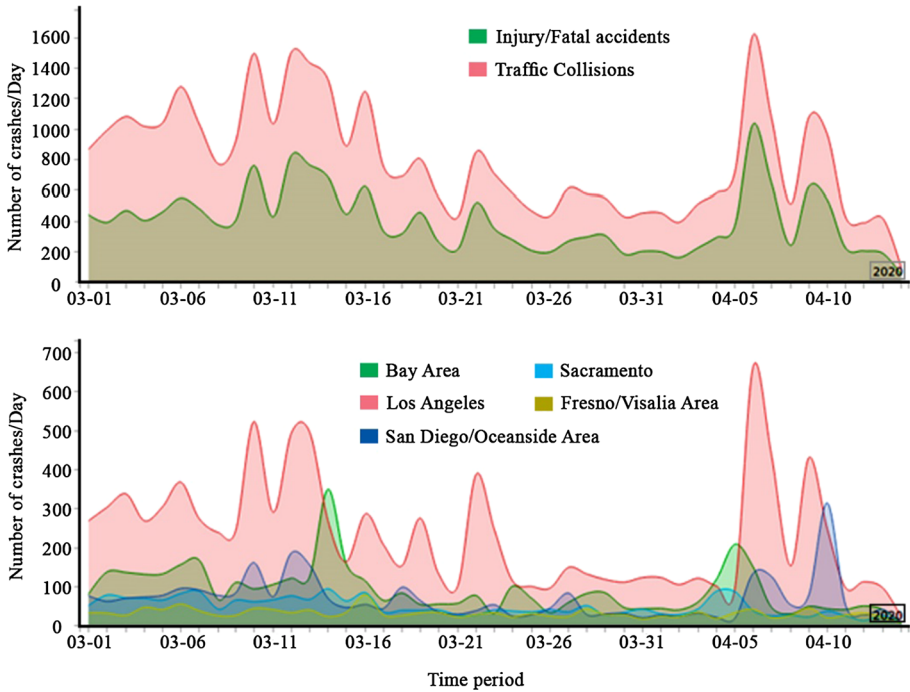
environment surveillance network in Pakistan to evaluate the presence of SARS-CoV-2. Their results indicated that environmental surveillance via wastewater could be effective for decision makers especially in societies where medical testing is limited; however, the quantification method of virus need to be investigated to enhance the sensitivity of SARS-CoV-2 detection in wastewater.

## 5 Traffic and transport

Transport and mobility of passengers are some of the most vulnerable aspects of the COVID-19 period. In particular, declines of commercial flight operation, demands of urban transport, public transport usage, and generally passenger transport, were the adverse impacts of the COVID-19 period on transportation. Also, freightage transit has been affected. On the other hand, these events have led to positive effects on the environment because of less energy demand in the transportation sector (Falchetta and Noussan 2020). Air traffic and public transport demand declined 90% and 80%, respectively, in Europe, and Road traffic fell down by 73% in the UK (Budd and Ison 2020). Even remote working has had positive effects on the environment by reducing transport emissions. Working from home less traffic pollution and commuting without harming the economy (Crowley et al. 2020).

Travel and economic activities have been drastically reduced because of lockdown measures worldwide, leading to a significant decrease in traffic congestion in major cities (Wang et al. 2020). For example, about a 50% decrease in peak traffic congestion was observed in US cities such as New York and Los Angeles. The correlative reduction in pollutants like carbon monoxide (CO) and NO<sub>2</sub> is the main result of this decrease in traffic (NASA 2020a; Saadat et al. 2020). The average level of CO in New York City has dropped by 50% compared to the previous year during the same period, and similarly, in Madrid, a 75% decrease in the average level of NO<sub>2</sub> was reported in March 2020. Recently, by studying the change in air quality and the potentially avoided cause-specific mortality during the lockdown in China, researchers have shown the health benefits of air quality enhancement due to the decrease in NO<sub>2</sub> and fine particulate matter (PM) from traffic (Chen et al. 2020). Regardless of having tremendous economic and social impacts, lockdowns have also some benefits in decreasing road crash deaths and disabling injuries by reducing travel (Worldbank 2020).

As one of the major side effects of COVID-19 induced lockdowns, traffic shrinkage induced a decrease of road accidents. A report provided by the Road Ecology Centre at the University of California Davis shows an almost 50% reduction in collisions and injury/fatal accidents as well as a \$40 million per day savings to the California public after the state's shelter-in-place order on 19 March. According to this report, the same reduction was seen in the Sacramento region. Figure 9 shows California's crashes during "Shelter-in-Place" orders, from March 2020 to April 2020, the top graph showing the number of crashes per day and the number of collisions/day where an injury/fatality happened. The bottom graph presents all crashes by area. It seems that heavy rains in the San Diego and Los Angeles areas caused a spike in crashes between April 5th and 10th, including injury/fatality crashes in both graphs (Shilling and Waetjen 2020). The figure, however, points to a significant reduction in collisions, particularly following heavy rains. Traffic maps created based on peak time travel at 8 am on April 8th, 2019, and at the same time for the same roads on April 6th, 2020, show significant reductions (more than 90%) in traffic across some

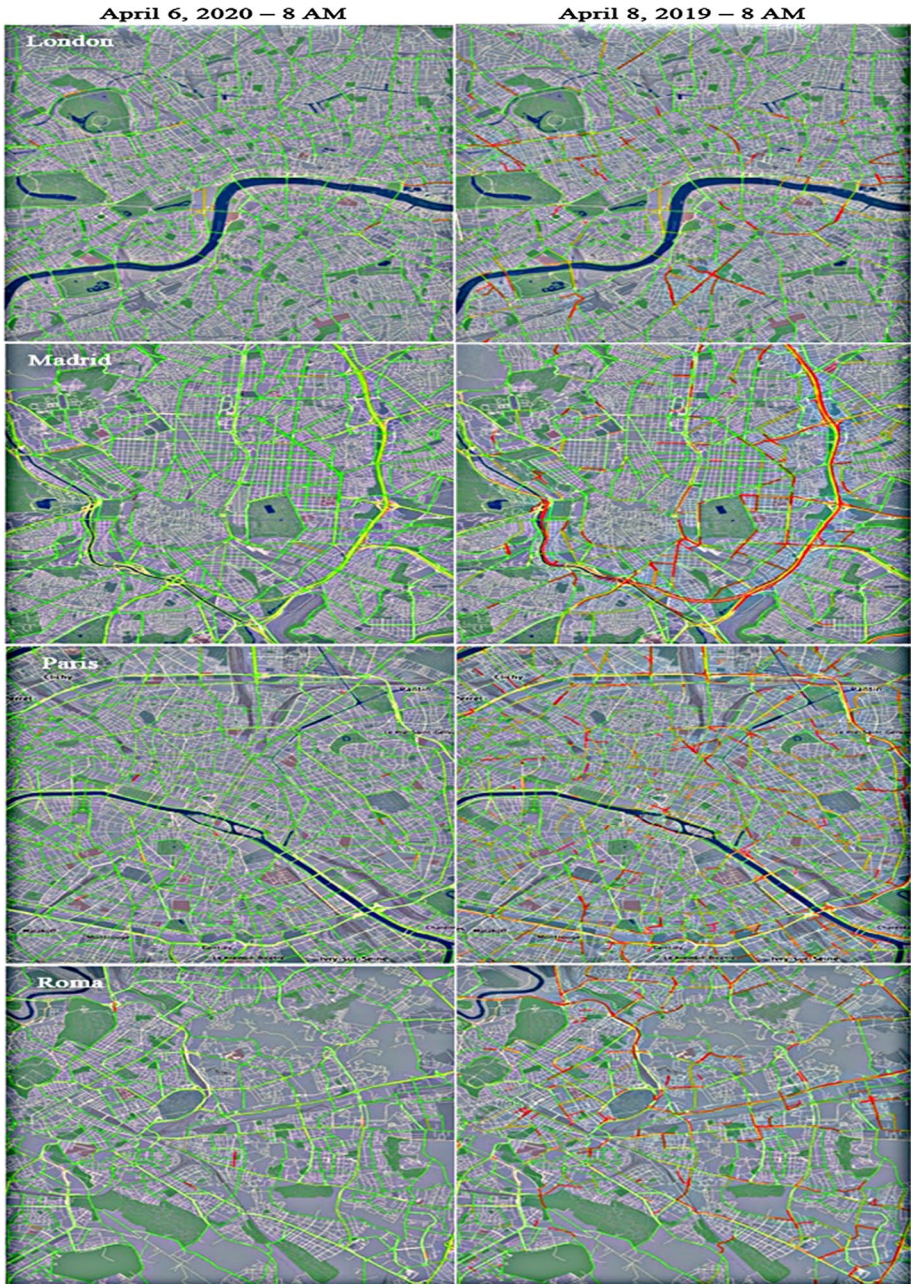


**Fig. 9** California crashes during “Shelter-in-Place” orders, when heavy rains in Southern California brought a brief return to “normal” conditions: (top) the number per day of all crashes and the number of collisions/day where an injury/fatality happened, (bottom) the rates of crashes occurred between March and April 2020. Both graphs show a significant reduction in collisions particularly following heavy rains, implying the positive impact of the pandemic. Modified after Shilling and Waetjen (2020)

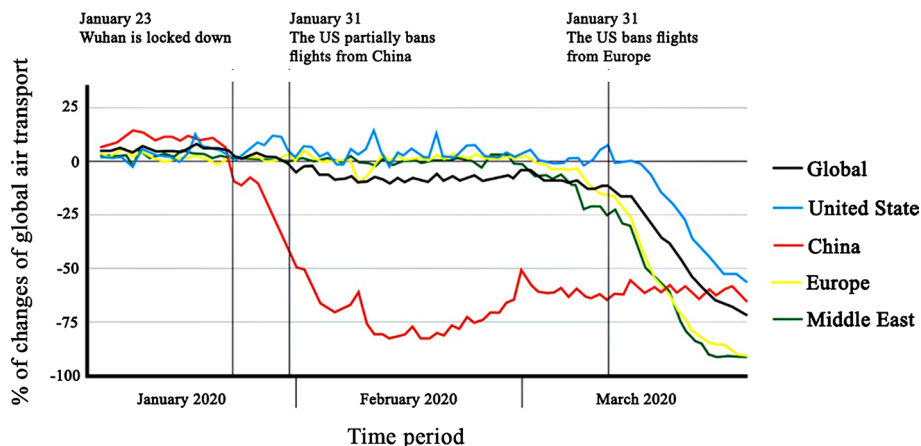
congested European cities including Paris, Madrid, Rome and London (see Fig. 10) (Dickson 2020). In Istanbul, traffic density before and after the closure of schools by the government was about 65% and 27% on March 16 (the day schools were closed). From March 5th to March 15th, 1 fatality was recorded in 790 accidents, whereas between March 16th and 26th 520 accidents occurred. Accidents dropped down to 34% during coronavirus related restriction (Dağ 2020). The long-term impact of the COVID-19 pandemic on traffic, transport, and mobility is hard to assess at present. However, some preexisting trends, such as the rise of sustainable mobility and remote working, have the potential to be established more strongly during the COVID-19 pandemic, leading to lasting effects on reducing carbon emissions as well as air pollution (Shi and Fang 2020; Worldbank 2020).

According to a report by the World Trade Organization, the disruption of economic activity owing to the COVID-19 pandemic has caused an estimated fall in world trade of between 13 and 32% (WTO 2020). Therefore, considering that the maritime industry handles over 80% of worldwide trade (UNCTAD 2018), this expected recession in global trade suggests a considerable decrease in human-based marine activity. Figure 8 shows the positive environmental impact of COVID-19 on the Canal City of Venice, Italy: note the decrease in commercial boating activities because of reduced tourism allowing the canal water to clear (Saadat et al. 2020). To the best of the authors’ knowledge, there is no study





**Figure. 10** Traffic maps of some congested European cities, including London, Madrid, Paris, and Roma. Green, yellow, and red routes show clear, moderate, and heavy congestions, respectively. As can be seen in the all cities, the pandemic lockdown significantly decreases traffic on April 6, 2020 (during lockdown), in comparison with April 8, 2019. While the reduction in traffic was more than 96% in Madrid, Paris, and Roma, it was around 90% in London. Modified after Dickson (2020)



**Fig. 11** Comparison of airline travel in 2020 for the COVID-19 period to the same time period in 2019. The global aviation industry slash flights as COVID-19 hits travel demand. In the context of the COVID-19 episode, strict lockdown laws have been enacted in some cities around the world. On January 23, 2020, the lockdown was implemented in Wuhan, which, as it turns out significantly reduced air travel up to  $-75\%$ —the biggest reduction to date by a China—in mid-February 2020. As of January 31, 2020, the United States imposed strict rules such as a flight ban from Europe and China, which did not see significant changes, but about two months later (late March) drastically reduce about  $-50\%$  was likely due to the US government's lockdown has been observed. Modified after Wastnage (2020)

available on the impact of the COVID-19 pandemic on ocean pollution, yet similar reductions are likely since maritime transportation has decreased significantly.

Because airlines are a significant factor in the international spread of COVID-19, governments have levied stringent restrictions on air travel, and, as a result, international air travel more or less ceased (Lau et al. 2020). As shown in Fig. 11, the global change in air traffic in early lockdown was around under  $25\%$ , and in the following the global air transportations were gradually decreased to  $0\%$  in February 2020. China, however, had an abrupt decrease (more than  $-75\%$ ) in late January to mid-February. From early to late March, the US, Europe, and the Middle East decreased air travel by—around  $50\%$ , these decreases reducing CO and  $\text{NO}_2$  in air. At this time, there was also an almost  $50\%$  reduction in collisions and injury/fatal accidents. Generally, as severe disruption occurs in industrial operations owing to epidemic or pandemic outbreaks, the transport volume is reduced, and thereby, positive impacts on the environment are appeared (Loske 2020). Though, positive impacts of COVID-19 on the environment such as the low generation of greenhouse gas emission are expected to have a reverse trend by returning to normal conditions. Therefore, the progress of green new action is indispensable (Tardivo et al. 2020).

## 6 Conclusion

COVID-19 has imparted many positive changes in the chemical composition of the environment worldwide. COVID-19 induced lockdowns have resulted in  $20\text{--}77\%$  reductions in emissions of nitrogen oxides, reducing by  $16\text{--}60\%$  in different cities. Emissions of  $\text{CO}_2$  were also reduced between  $5$  and  $10\%$ . Similarly, the particulate matter level globally was found to reduce by  $9\text{--}200\%$ , and New Delhi, India, witnessed the highest levels of change ever seen. The reduction in CO levels has also followed a similar trend, the level of

reduction between 30 and 60%. This might be due to reductions in the use of fossil fuels as the expenditure of the global fuel supply has decreased by 4% in 2020 in comparison to the same time in 2019. This is supported by an 8% reduction in the use of coal by April 2020 as compared to April 2019. A drastic reduction in vehicular operation also was a contributing factor regarding reductions in air pollution, as traffic congestion decreased worldwide up to 50%. The quality of several water bodies has improved seeing an increase of up to 79% dissolved oxygen levels. Conventional energy demands, for example, electricity, has also declined by almost 30% in many countries: a 12–20% drop in consumption of electricity has been recorded in most countries. Despite the disruption to economic activity (13–32%) globally, COVID-19 has created enormous positive effects on the environment, which must be considered as spotlights for the better management of the environment in the future.

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