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ORIGINAL PAPER

Environmental and air quality based impacts of COVID-19 on some countries around the globe: a spatiotemporal perspective

Tariq Sardar[1] · Afnan Ullah[1] · Irfan Ullah[2] · Abdur Rashid[3]

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Abstract
Coronavirus disease (COVID-19) is a novel pandemic disease and was first identified in Wuhan, China, at the end of 2019. It has affected the whole world in a short period of time and declared as a sixth global health emergency as it disturbed routine of human being and all life activities. This study presents a review focusing on ongoing pandemic as a disaster that provided a way of opportunity for change towards potentially positive and negative impacts on the environment. The observed positive aspect for environment in the context of short time impacts are improvement in air quality due to reduction in greenhouse gas emission, noise, nitrogen dioxide, and particulate matter $< = 2.5$ µm experienced in countries including India, Pakistan, China, USA, Italy, France, Spain, and other European countries. The observed negative impacts include organic waste generation and its mismanagement due to lockdown, non-functioning of waste recycling plants, municipal activities, and medical waste of materials used for personnel care protection. The study is explored through image data available from European Space Agency and National Aeronautical Space Agency to assess positive and negative impacts on environment. With available environmental observations, this review aims to assess impacts of current pandemic on environment focusing on some major Asian, European countries and USA. The present approach enabled determining changes with positive and negative effects on the environment. The observed assessments provide spatiotemporal based support for theoretical perspective that pandemic disasters can provide a way of opportunity for positive change in environment with slight negative environmental change.

Keywords Air quality · COVID-19 · Environmental observations · Greenhouse gas emission · Organic waste

Introduction

Emerging infectious diseases are a critical challenge in the twenty-first century. The present pandemic of new coronavirus pneumonia (coronavirus disease 2019, COVID-19), officially termed as a COVID-19 by World Health Organization (WHO) (Chen et al. 2020a), is becoming a global challenge in all aspects. Coronaviruses are single-stranded RNAs with a diameter ranging from 80 to 120 nm that can infect humans, as well as a wide number of species (Kooraki et al. 2020). International Committee on Taxonomy of Viruses named SARS-CoV-2 as coronavirus-2 (Gorbalenya et al. 2020).

The COVID-19 outbreak has a high similarity with the severe acute respiratory syndrome (SARS) outbreak that occurred in 2003, as both were caused by new coronaviruses (Chen et al. 2020b). Due to people grouping for New Year celebration, the number of cases were increased (Phan et al. 2020; Riou and Althaus 2020). The pandemic was first identified in Wuhan, China, with initial cases related to the causes of the wholesale sector for seafood (Yang et al. 2020).

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✉ Tariq Sardar
tariqsardar@kust.edu.pk

Afnan Ullah
afnanmarwat279@gmail.com

Irfan Ullah
irfanullahkhan75@gmail.com

Abdur Rashid
rashid.a2010@yahoo.com

1 Department of Environmental Sciences, Kohat University of Science and Technology, Kohat, Pakistan

2 Department of Biotechnology and Genetic Engineering, Hazara University, Mansehra, Pakistan

3 School of Environmental Studies, China University of Geosciences, Wuhan 430074, People's Republic of China

The WHO reported a cluster of cases in Wuhan in January 2020, which spread throughout the country and turned into an epidemic in end of month (Dutheil et al. 2020). Till the present time, while the COVID-19 is again emerging with its third wave, it has not only affected the China but also affecting the whole globe. The WHO has declared this epidemic to be the six global health emergencies of the time.

Being an emerging research domain, a critical review of studies focusing on relation between the ongoing pandemic of COVID-19 and the environment can produce a valuable approach of knowledge that could provide directions to related applicable studies. Furthermore, such focused study will be insightful in aspect of methodological advancement, which can be applied in the context of other related countries to prospectively investigate the nexus between COVID-19 and the environment.

Methodology

This study was performed by exploring the available imagery-based data from European Space Agency (ESA) and National Aeronautical Space Agency (NASA). With the help of available environmental observations, imagery-based data and mapping were electronically collected from their official data databases. The collected spatial data include mean tropospheric nitrogen dioxide (NO_2) density, column and graphs, and greenhouse gas (GHG) emission from the GHGSat-D Satellite observations.

This study presents information and data with a focused objective to spatiotemporally assess the environmental impacts of COVID-19, as well as to present prospective approach for related studies.

Environmental impacts of COVID-19

There are clusters of environmental issues since industrialization including pollution of water and air, degradation of ozone layer, climate change, depletion of groundwater level, and many others (Bremer et al. 2019). While global warming results due to the increased rate of GHGs, with overpopulation, an increase has been observed in its daily usage. The world environment is going to be degraded because of the overpopulation, infrastructure development, luxurious life, etc. Industries are producing air, water, and land pollution, as well as transportation is also affecting the environment. The ongoing novel COVID-19 pandemic is affecting the whole globe at different level and different aspects, and has particularly impacted the environment in both positive and negative ways.

Positive impacts

COVID-19 pandemic is affecting the whole world. The industries, transport, flights, and many such activities are disturbed which has affected our environment in positive way. The random lockdowns have resulted into negligible production of trash, air pollution, and many other related factors. The climatologists has also observed that GHG emissions have decreased to such a level that have not been seen before World War II (Global Carbon Budget. 2020). China, USA, Italy, Iran, Taiwan, Spain, Pakistan, Turkey, Germany, South Korea, UK, France, India, and other countries remain under lockdowns either partially or completely for random time periods which has also positively impacted the terrestrial environments.

From non- or limited functioning of industries, waste production and emissions have reduced to a large extent. Particularly, limited emission of greenhouse gases and toxic minute particles has been observed. These all aspects are explicitly observed from the NASA released imagery data focusing on China showing environment restoration during the current pandemic (Fig. 1).

Air quality

Quality of air is significant for the well-being of humans. However, 92% of the world population resides in countries where the poor air quality has reached to critical levels (WHO 2016). Pertaining to this, the WHO 2016 study showed that approximately 8% of the total deaths in world are due to air pollution (WHO 2016). NO_2 (nitrogen dioxide) is one of the reactive air pollutants, released particularly through fossil fuel combustion. It is known to be harmful to public health and studies indicate that mortality rates increase due to its exposure (Faustini et al. 2014). Due to COVID-19, lockdown has decreased the transport operations which has led to less energy usage and lower demand for oil resulted into positive effect on the quality of the environment. New data trends show that air efficiency has increased and NO_2 emissions have been decreased to 30% which has been observed by NASA and ESA satellite imageries. The data was obtained from ESA via the satellite Sentinel-5P, TROPOMI, as well as from NASA focusing on NO_2 concentration in different regions of world.

Ambient noise is one of the major irritation sources for individuals and environment. While as per WHO guidelines, the sound level needs to be 30 decibels at night for better sleep. Due to traffic controls and self-quarantine policies, noise reduction was also experienced during lockdown in major cities around world.

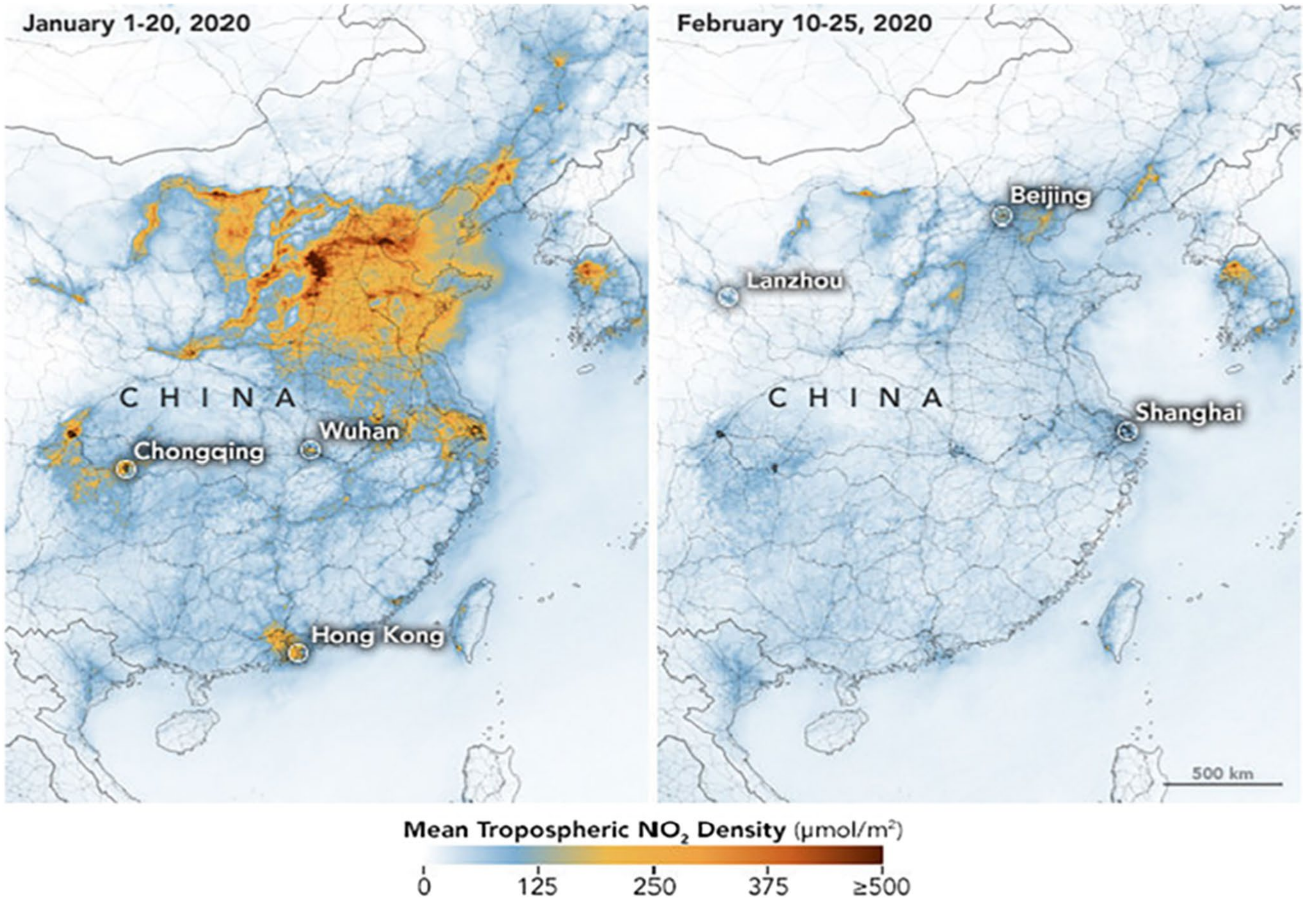

Fig. 1 Reduction in NO_2 emission in major cities of China (before and after lockdown: January 1–20, 2020, to February 10–25, 2020). (Image source: ESA 2020)

Pakistan

The estimated decrease in NO_2 amounts across main cities in Pakistan before (1 March–23 March 2020) and after lockdown announcement (24 March–15 April 2020) is shown in the graph (Fig. 2). During lockdown, the quantity of air emissions and particulate matter become lower substantially due to a decrease in consumption of fossil fuels and other related sources of emissions. The Pakistan AQI (Air Quality Index) standards improved significantly after shutdown of factories and transport. While no official figures on air pollution are available, a clear difference was observed in several cities before and after the lockdown. During the lockdown on 24 March 2020 in Pakistan, some week-based data show that it has led to a potential decrease in the amount of air pollution in many cities (Fig. 2).

India

The concentration of NO_2 in India during 2019 and 2020 is shown in Fig. 3. On 25 March 2020, the government of India halts large population in lockdown in order to stop further transmission of virus. New satellite-generated maps (based on data from the Copernicus Sentinel-5P) show NO_2 average concentrations over India between January 1, March 24, and 25 (first lockdown date) till April 20, 2020, relative to the same duration in last year. A total of 40–50% of reduction has been detected in Delhi and Mumbai as compared to last year during same time (ESA 2020).

China

Reduction of NO_2 and PM $<=2.5$ μm was experienced in China as quarantine was firstly implemented there. NO_2 decreased by 2.8×10^{-9} kg/m^3 and 1.29×10^{-8} kg/m^3 in overall China and in Wuhan city with a decrease of 1.4×10^{-9} kg/m^3 in PM $<=2.5$ μm respectively, as well as decrease of 1.89×10^{-8} kg/m^3 in more than 360 cities. In China, NO_2 emission progression prior to the lockdown and after lockdown is shown in Fig. 1, whereas NO_2 emissions are lowered by 20–30% from 10 to 25 February during lockdown. The

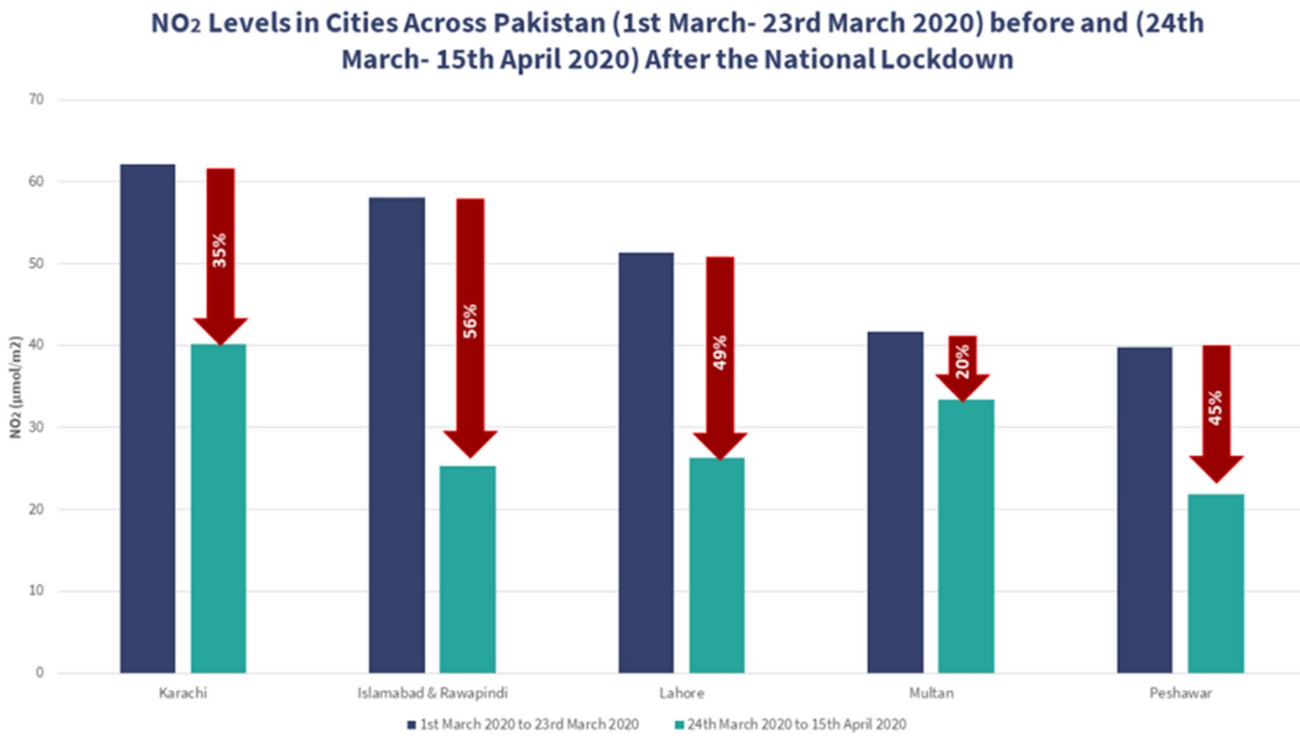

Fig. 2 Mar 1st–15th April 2020 emission of major cities of Pakistan

satellite image was collected using TROPOMI by Sentinel-5P satellite (ESA 2020).

On January 23, 2020, quarantine approach was implemented in Wuhan city to control the spread of the disease. As shown (Fig. 4), levels of NO_2 decreased up to 30%. The NO_2 emissions were monitored by a Sentinel-5P satellite. A clear comparison is depicted by comparing the same duration during 2019 and 2020 which specifically demonstrates that during COVID-19 pandemic, NO_2 emissions have reduced considerably.

European countries

The average NO_2 level in the five major cities of Europe is shown in Fig. 5. The upper graphs present NO_2 values (using moving average for 14 days) in 2019 in comparison to the Sentinel-5P 2020 data, while the lower graphs display in situ observations. The gray shades depict the 2020 quarantine stage, steadily moving from tight to relaxed gray steps, with the figures displayed in red representing decline over the period in 2020 compared to the 2019. A great decrease of NO_2 (40 to 50%) has been detected.

France The France NO_2 emission progression (No_2 tropospheric column) prior to lockdown and after lockdown is shown in Fig. 6. These emissions decreased up to 20–30% from March 2019 to March 2020 during the lockdown (ESA 2020).The satellite image was obtained by the ESA satellite Sentinel-5P instrument. As depicted, NO_2 emissions have been decreased significantly after lockdowns across Paris and other big cities due to limited transportation.

Italy The NO_2 pollution spatial amount in Italy during months of March 2019 and March 2020 is shown in Fig. 7. The imagery observation indicates that NO_2 concentration has decreased dramatically during lockdown. Emissions of NO_2 was reduced from 20 to 30% across Italy (ESA 2020).

Spain In Spain, NO_2 emission progression prior to lockdown and after lockdown is shown in Fig. 8 with a decrease of 20 to 30% (ESA 2020). The satellite images display the NO_2 values from March 14 to 25, 2020, as compared to the monthly average of 2019 values.

United States of America

Accumulation of NO_2 pollution in northeastern region of the USA, from March 2015 to 2019 and 2020, is shown in Fig. 9. This image was obtained from NASA (AURA satellite). The spatial results depicts that up to 30% of NO_2 concentration has been substantially decreased in this region after lockdown (NASA 2020).

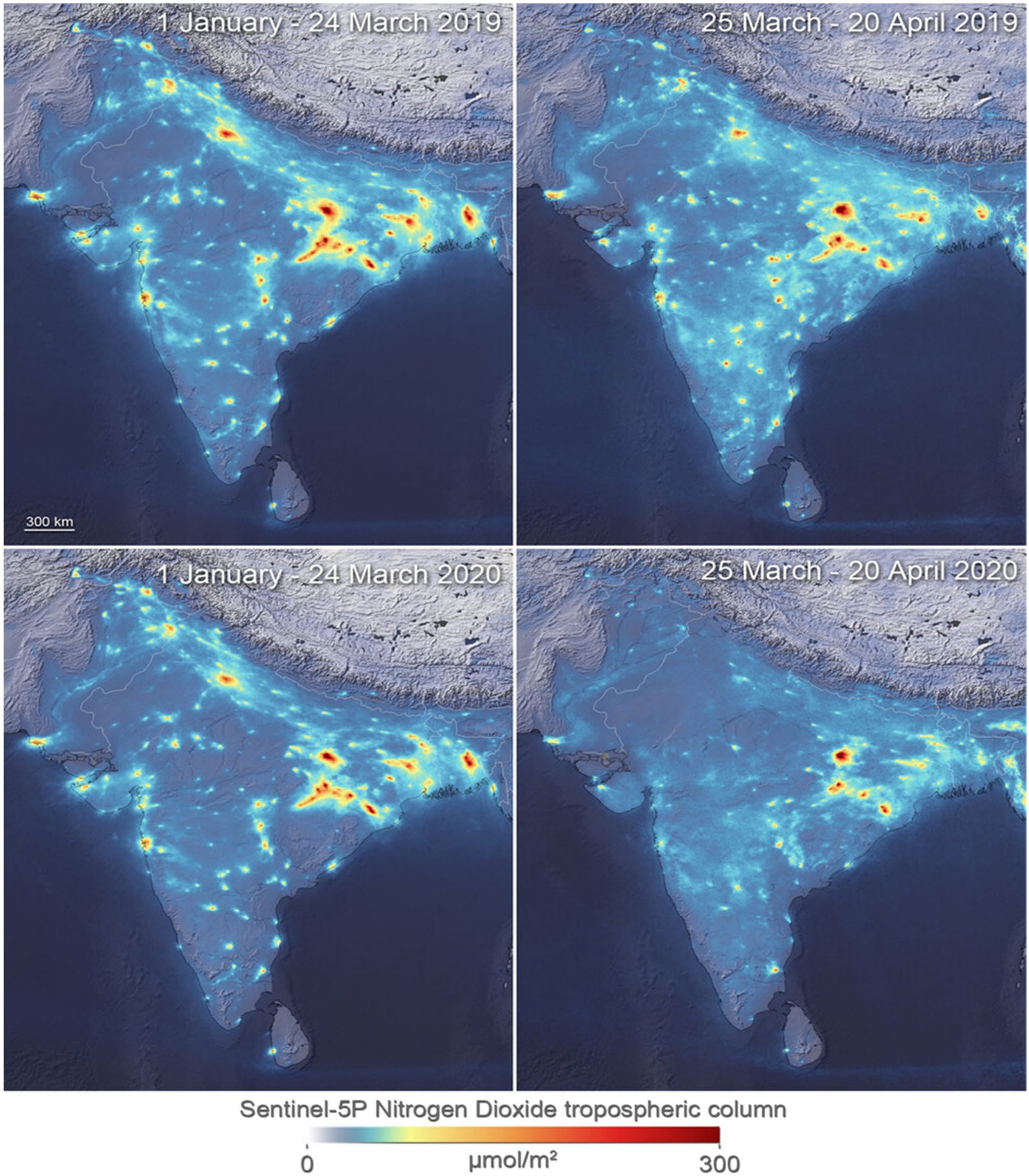

Fig. 3 Before and after lockdown NO_2 emission over India (ESA 2020)

Marine environment

The aspects of human activities towards ocean have been significantly altered due to pandemic. Seaport restrictions and shifts in consumption habits have affected a wide range of maritime industries, especially fisheries, passenger ferries, and fishing boats. Shipping has been reduced worldwide which has positively impacted the marine environment

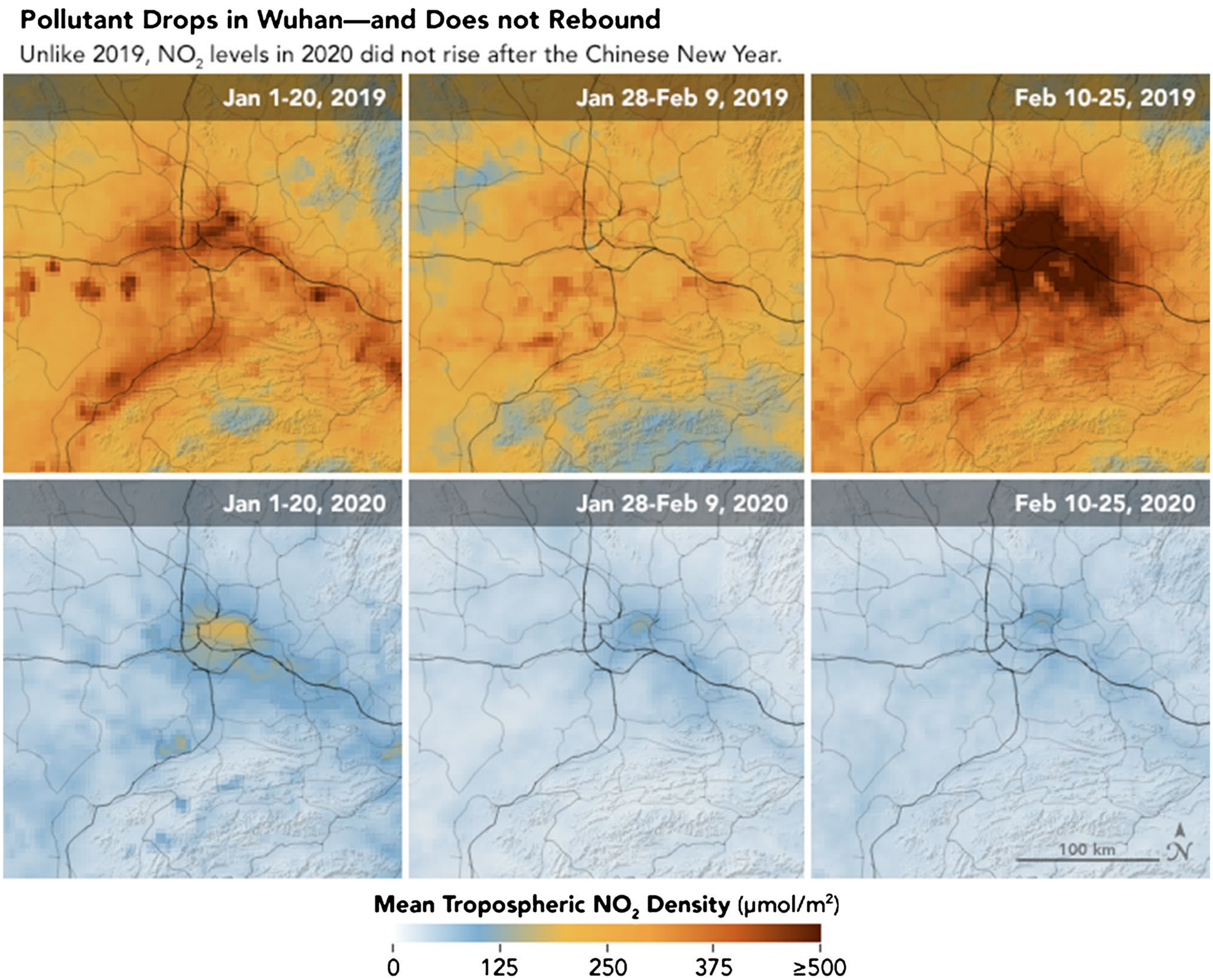

Fig. 4 January 1, 2019–February 25, 2020 NO_2 emission in Wuhan (ESA 2020)

due to reduction in marine pollution, particularly oil spills and other effluent.

Negative impacts

Beside positive impacts of COVID-19 on environment from the spatiotemporal based observations of major countries, there are also related negative impacts.

Increased waste

Biodegradable and non-biodegradable waste processing produces many environmental problem like degradation of soil, water, and air pollution (Schanes et al. 2018). Additionally, a huge production with unplanned dumping of waste has been observed in recent decades (Al-Fare et al. 2010). Particularly during pandemic, restricted movement of people has raised their needs for online or home delivery-based services. Home-delivered food is often wrapped in plastic or other such material bags which has produced more waste. Due to households, biodegradable waste production has also been increased to a larger extent.

Medical waste is considered a special class of hazardous pollutants because its improper treatment can cause secondary environmental pollution, particularly in such crisis situations. There is research gap focusing on spatiotemporal heterogeneity of this infectious waste (Wei et al. 2021). During COVID-19, medical waste become potentially infectious due to survivability of the virus in it, therefore termed as epidemic waste. Hence, during pandemic, storage basis of such hazardous waste become extended particularly in cities of Wuhan (China), New York (USA), and Lombardia (Italy). During early stage of COVID-19 outbreak, in Wuhan (China), the storage capacities for health care wastes (HCWs) were insufficient

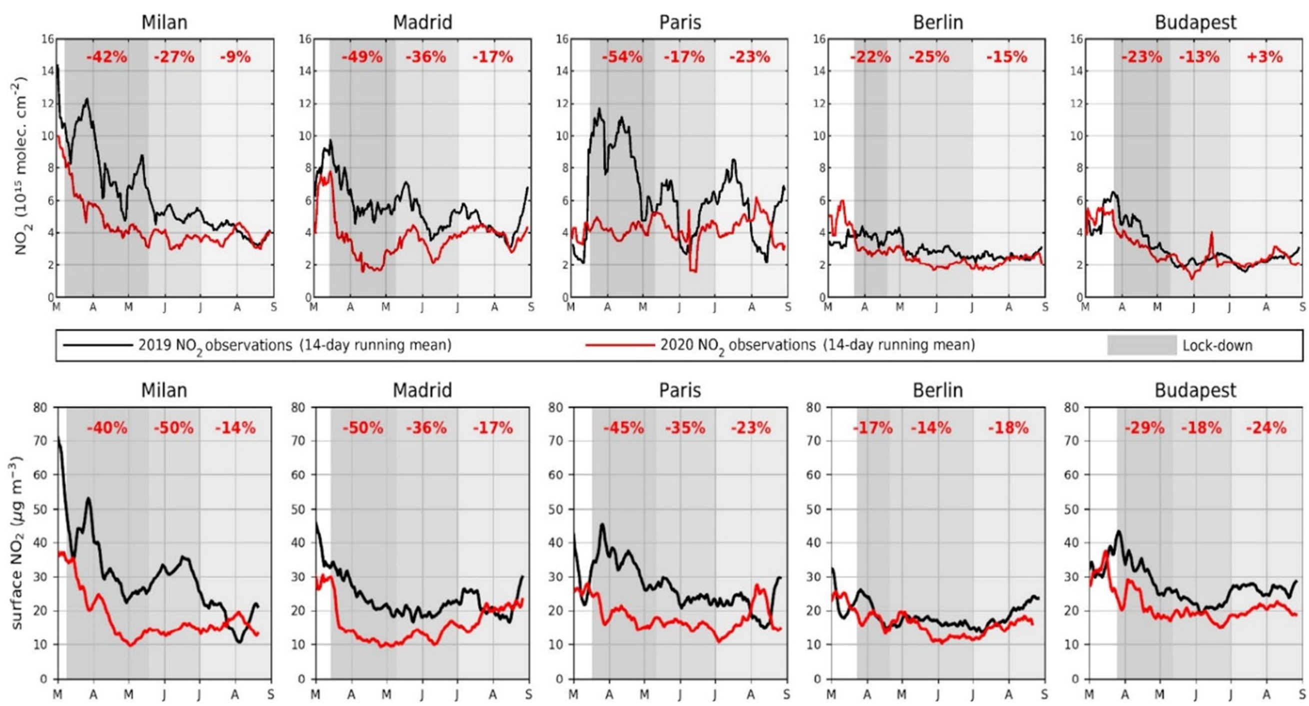

Fig. 5 Nitrogen dioxide concentrations observed over major European cities (ESA 2020)

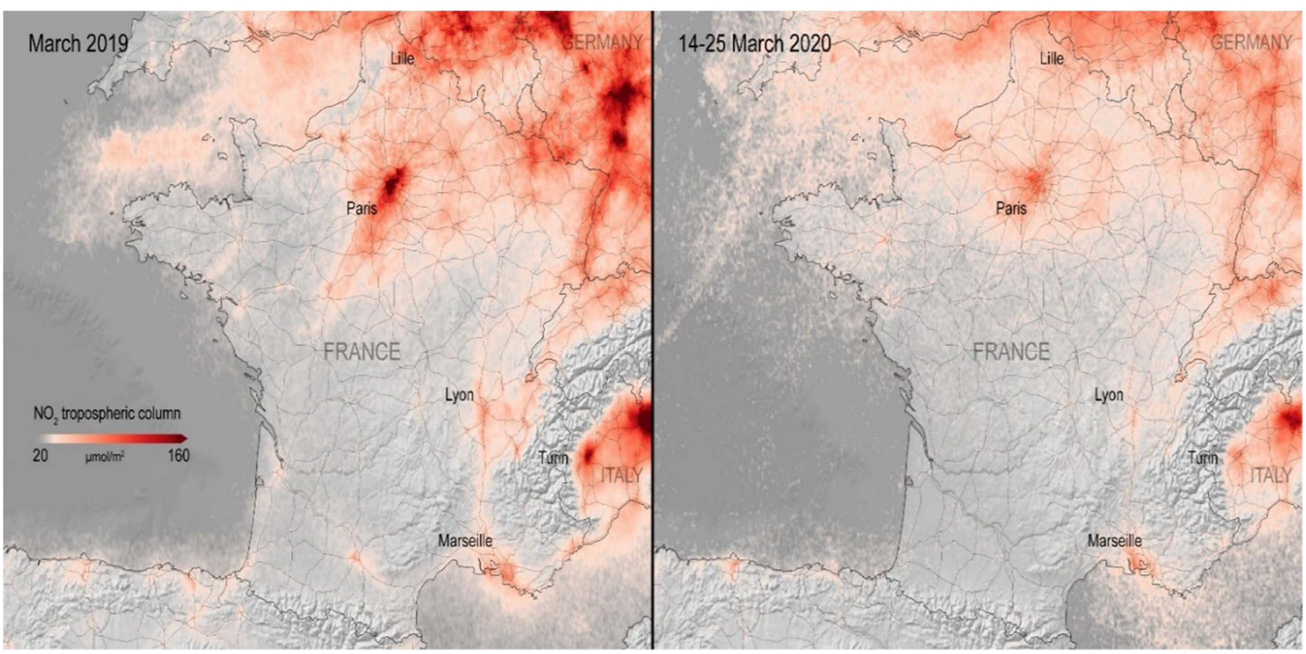

Fig. 6 Concentrations of nitrogen dioxide through France (ESA 2020)

due to its abrupt generation in many hospitals and isolation centers as shown in Fig. 10 (Yang et al. 2021).

On the other hand, medical supply chains and logistics were actively operative for resources provision. Since these include mostly disposable items, they become part of medical waste and consequently can be hazardous due to infectious properties (Qadis et al. 2020). The Wuhan hospital in China, for instance, generates averagely 240 metric tons of medical waste in a day after the epidemic.

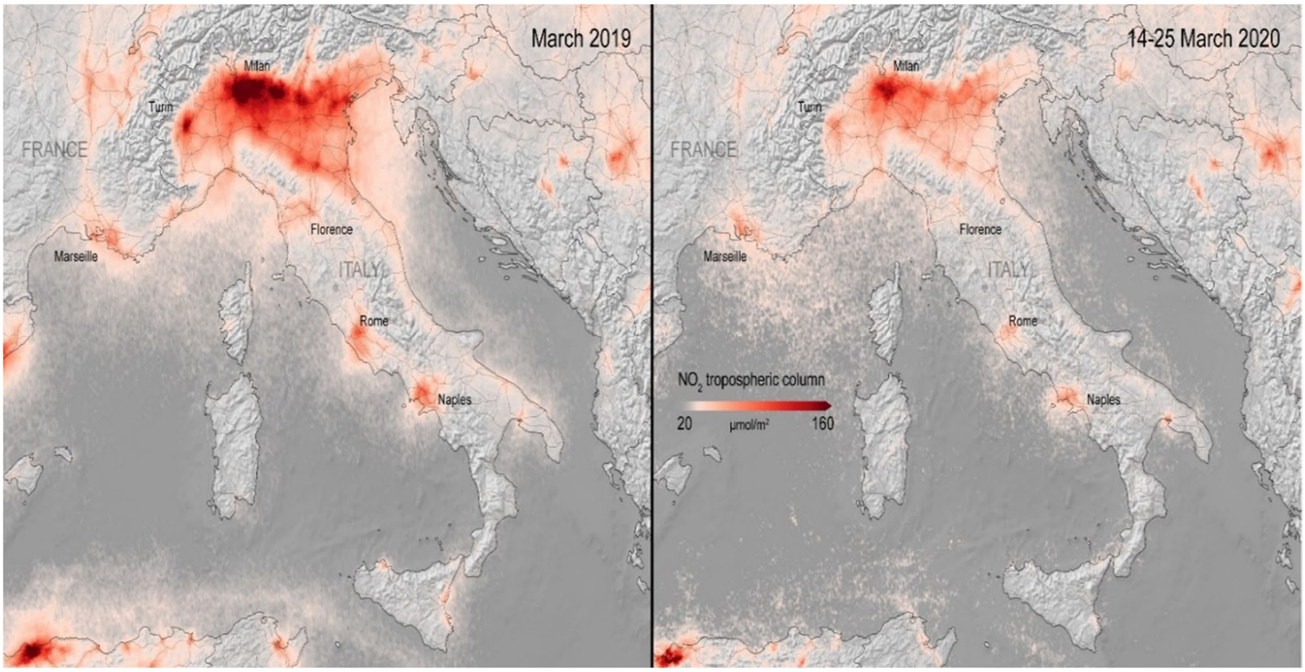

Fig. 7 Concentrations of NO_2 through France (ESA 2020)

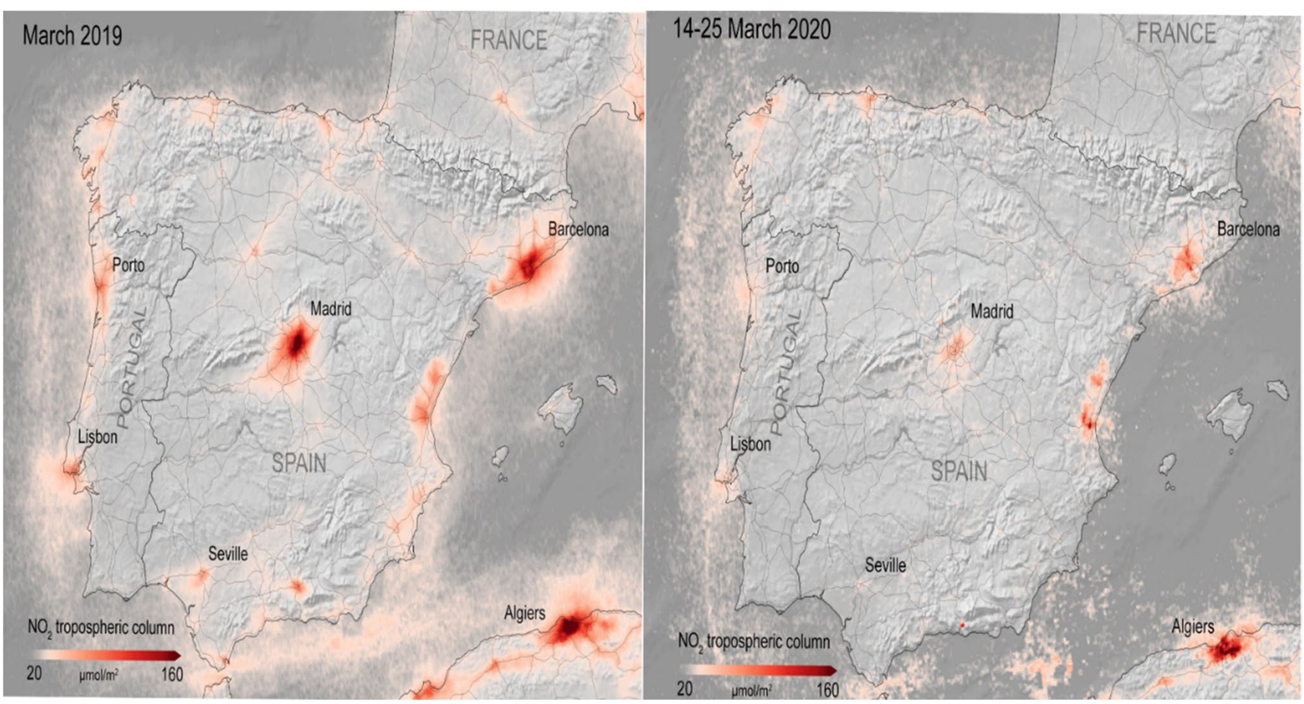

Fig. 8 Spain NO_2 emission before and after lockdown (ESA 2020)

Focusing on the hazardous effects from the medical waste generated during pandemic, the American Association of Poison Control Centers surveillance team and Centers for Disease Control (CDC) comparatively analyzed the chemical exposure numbers (reported during January to March 2020) with the number of reports during the same months during the years 2018 and 2019 respectively. The resultant data shows that poison centers received 45,550

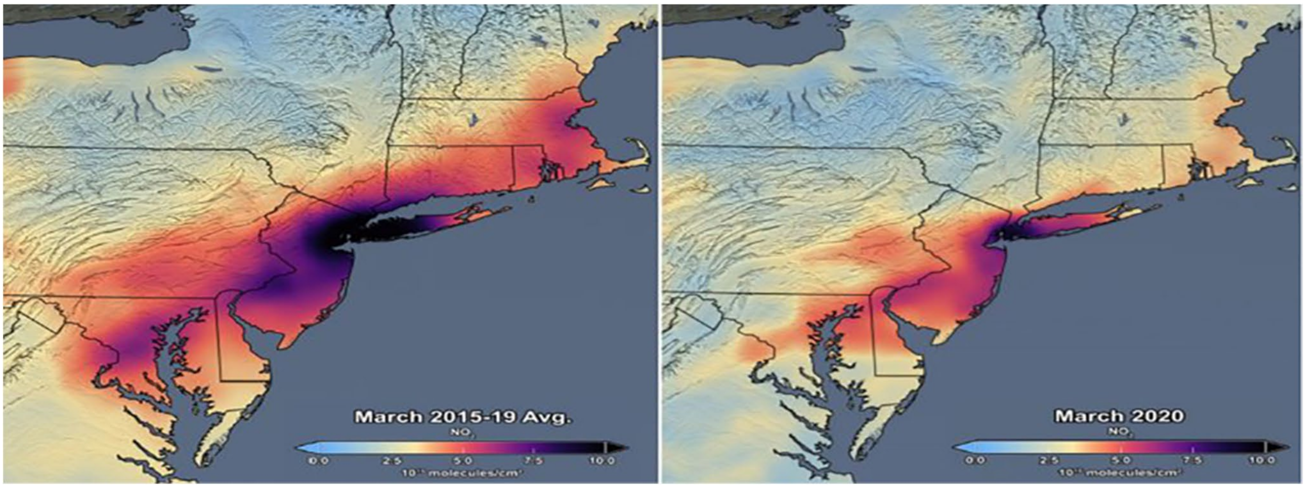

Fig. 9 NO_2 emissions in northeastern USA before and after lockdown (NASA 2020)

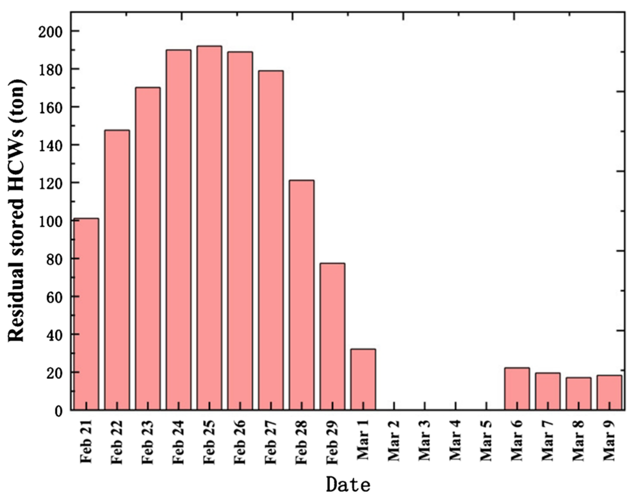

Fig. 10 The increasing amount of the stored HCWs (February–March 2020) during COVID-19 pandemic in Wuhan, China (Yang et al. 2021)

chemical exposure calls during January–March 2020. The exposure calls include 28,158 related to cleaners and 17,392 related to disinfectants, depicting a total increase of 20.4% and 16.4% (January–March 2019 and January–March 2018, respectively). It shows a direct temporal relation of poison exposure with an increase usage of these products. The study-based analysis shows that due to cleaner and disinfectant exposures, daily number of calls increased significantly at the beginning of March 2020, as shown in Fig. 11 (Chang et al. 2020).

There has also been increase in other related waste produced from personal safety materials in major countries such as the USA (Calma 2020). The adverse consequences due to this kind of waste are far-reaching. This can be probably used by animals to consume their food in open environment and may resultantly contribute to their death.

Waste recycling reduction

Waste disposal is one of the most significant environmental issue and of concern to all countries (Liu et al. 2020). Quarantine measures caused a rise in trend of online shopping of daily life essentials and home distribution of food items in many major countries. Consequently, it has raised the volume of household waste due to shipped packaging materials (Somani et al. 2020). Recycling of waste is, however, an efficient method of avoiding waste, energy saving, and conserving of resources found naturally. However, some countries have suspended the waste recycling due to progressive COVID-19 pandemic for controlling virus transmission. In many cities, the USA has limited recycling programs (approximately 46%), as the government was concerned about spreading of pandemic (Somani et al. 2020). In many other major study countries, infected people were restricted from the waste collection (Zambrano et al. 2020).

Other negative impacts

Significant quantities of disinfectants have recently been used in roadway, residential, and rural areas to control the spread of virus. Overuse of disinfectants can destroy the beneficial species and, hence, can cause an environmental imbalance (Didar-Ul Islam and Bhuiyan 2016). Focusing on present study countries, China has throughout contributed much efforts on the disinfection process for the control of COVID-19 virus spread. However, excessive use of disinfectants including chlorine can consequently produce the toxic by-products (Zambrano et al. 2020).

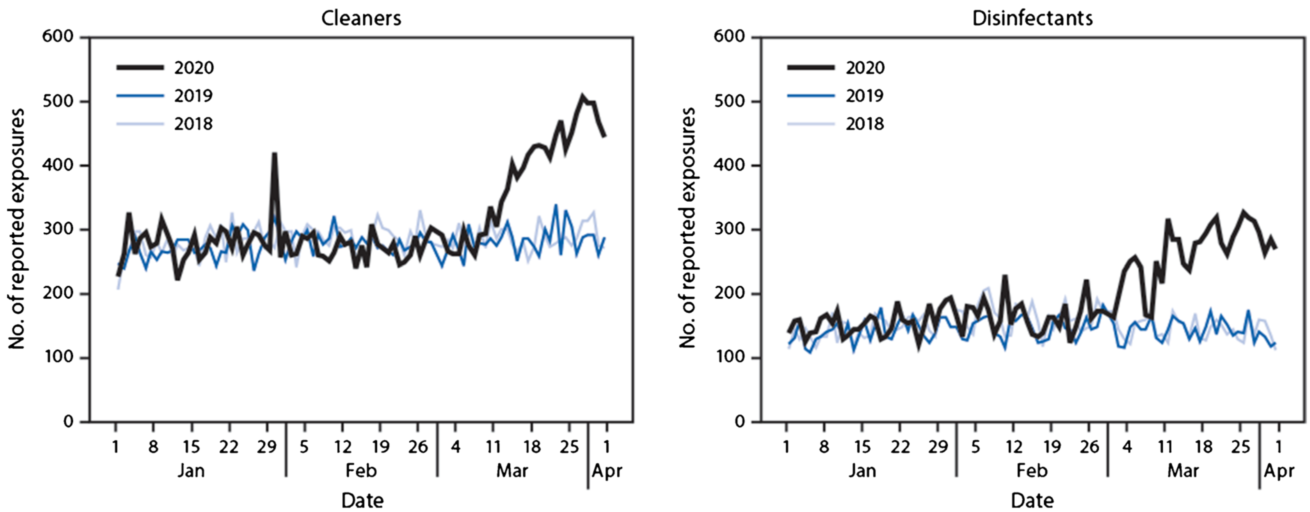

Fig. 11 Number of daily exposures to cleaners and disinfectants reported to US poison centers — USA, January–March 2018, 2019, and 2020 (Chang et al. 2020)

Conclusion

The present study has presented a review-based approach to spatiotemporally elaborate the positive and negative impacts of COVID-19 pandemic on environment with a focus on some major Asian, European countries and USA. In aspect of looking at both sides of the coin, lockdown during pandemic played a critical role towards environmental performance. We conclude that initial lockdowns during pandemic have led to the potential improvement in environmental quality. The quality of air has been improved due to GHG reduction and related pollution. The consecutive lockdowns have considerably declined the transportation which has consequently reduced the noise level as well. Additionally, CO_2 and PM $<=2.5$ µm level reduction was also experienced in different countries. Along positive impacts, based on mixed results, the COVID-19 is also affecting environment in negative way including production of organic waste and medical waste, as well as reduction in waste recycling due to restricted transportation. Other negative impacts relate to the use of disinfectants which may create environmental imbalance due to its toxic effects on beneficial microorganism. All these related impacts can be temporary as it is unpredictable to give final facts and figures about persistence of environmental quality on sustainable basis. Due to the need-based life during pandemic, it can be suggested to prioritize the "clean and green" way of life and related activities. Prospectively from such experience, time-orientated efforts need to be taken focusing on preventive and applicable measures for an eco-sustainable environment.

Declarations

Conflict of interest The authors declare that they have no competing interests.

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