

Part V

Outlook

13

Effects of COVID-19: An Environmental Point of View

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13.1 Introduction

The emergence of Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) (β -coronavirus) in Wuhan, China, in late December 2019 has created unprecedented devastating effects on social, economic, public health, and global environmental status with an alarming spike in mortality and morbidity. The novel coronavirus disease (COVID-19) is characterized as SARS-CoV-2 or simply put as CoV, which has generated such a global awareness in terms of the magnitude of infected patients, mortality rate, socioeconomic impact, public health exacerbation, and environmental degradation globally [1]. It has received much attention because of its impact on the environment, socioeconomic development, and health outcome [1, 2]. CoV belongs to the family “Coronaviridae” with four subfamilies, namely, alpha (α), beta (β), delta (δ), and gamma (γ). It has been reported that the α - and β -CoVs are pathogenic in human beings [2, 3]. The emergence of the virus was recorded in the Hubei province, Wuhan city, China, and it eventually spread across all the continents and was unanimously declared as a global pandemic by the World Health Organization [4]. The pathogenic β -coronavirus is novel in the sense that it is the first pandemic recorded in history to be caused by a coronavirus – the type that is rare and transmits rapidly

through contact with liquid, sputum, aerosols, and nasal fluid of infected individuals [4, 5]. Aerosols may penetrate the human respiratory system through inhalation through the nose or mouth [6, 7].

There is a long history of reported cases of similar global epidemics of the twenty-first century, and all share a common cause of pandemic events found in the close interaction between human populations with domestic and wildlife pathogens [8]. These pathogens are transmitted to the host community either by contact or aerosols or via consumption. Notable of the recorded epidemics were the SARS in 2003, which claimed 8000 infections with a mortality rate of 10% [9], Middle East respiratory syndrome (MERS) in Saudi Arabia and Jordan in 2012 – a zoonotic disease that recorded sporadic cases because of community crowding [10], the 2009 H1N1 influenza swine flu virus that stemmed from Mexico and the United States with a mortality rate of about 0.4% [11], and the Ebola virus that was first detected in 1976 in formerly known Zaire had boasted of about 28 000 confirmed cases with 11 000 deaths in Sub-Saharan African countries [12]. Other pandemic outbreaks include, but are not limited to the Zika fever from 2015 to 2016, the Avian flu [12–14].

The global spread engulfing almost 215 countries in all the continents of the world except Antarctica has generated much concern. It has spurred every country's National Disease Control unit to action on instituting COVID-19 prevention protocol and building capacity for research tailored toward understanding the novel virus, with the golden goal of developing an antiviral vaccine. According to the World Health Organization (24–30 August) weekly epidemiological update report that was assessed on Friday, 4 September 2020, about 1.8 million new COVID-19 cases and 38 000 new deaths were documented in the week ending 30 August [15]. The results indicated a 1% increase in the number of cases and a 3% decrease in the number of deaths than the previous week, i.e. 17–23 August. As at the end of August 2020, an alarming cumulative total of about 25 million cases and 800 000 deaths had been reported since the start of the pandemic. Figure 13.1 shows the number of cases and deaths reported weekly by the WHO from 30 December to 30 August 2020.

The preventive measures targeted at reducing and preventing the communal transmission of the virus varied from travel restrictions, contact tracing, social distancing etiquettes, good hygiene, ethanol sterilizer usage, face masks, and performance of massive COVID-19 screening tests. Informed measures on social distancing and isolation, when religiously adhered to by citizens, have offered a substantial decline in transportation/travel as a result of employees working remotely from the comfort of their homes. Groceries, basic needs, and essential items are ordered online. In highly developed countries such as China, Japan, and South Korea, drones and robots deliver packages with the highest hygiene level, strict adherence to COVID-19 protocol, while ensuring excellent service delivery. Travel restrictions enforced by many countries have been the reason for a significant reduction in the use and demand for oil and its products, consequently resulting in a lesser carbon footprint as a result of lesser smoke emission

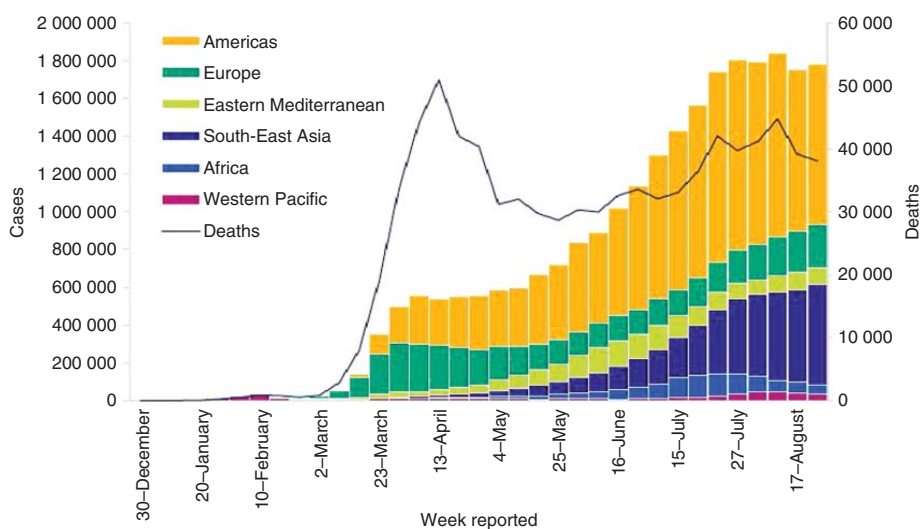


Figure 13.1 Weekly COVID-19 cases and deaths from 30 December to 30 August 2020. Source: WHO [15].

from manufacturing industries and other point sources and, of course, a cleaner atmosphere.

These practices indicate that priority has been solely hinged on public health safety, but little is being done on important environmental implications of the virus. It is highly likely that some countries may forgo sustainable environmental impact assessment of the virus and rather focus on pursuing the rapid economic growth of the nations. However, it is logical to state that an improvement of environmental quality and climate systems will generate a consequential improvement in the economy and hence the health and well-being of citizens. Therefore, the authors have taken a holistic approach in identifying numerous effects of COVID-19 on environmental systems, public health, and socioeconomic parameters of the world. The study aimed to analyze the myriad effects of COVID-19 on environmental parameters by evaluating the current global status of COVID-19 and proffering well-informed and sustainable solutions to assess the environmental effects of the COVID-19 pandemic.

13.2 Methodological Approach

This chapter has taken a holistic and thorough look at the effects of the COVID-19 pandemic from an environmental perspective. In order to address the objectives of this chapter, a three-stage approach was embraced. At first, the literature search was thoroughly conducted by the extraction of relevant peer-reviewed literature, papers, newspapers, book chapters, web scripts from Scopus (www.scopus.com), and Web of Science (www.webofknowledge.com) databases, and specifically, the WHO website. This was done by critically assessing a large volume of indexed documents from searches using relevant keywords such as “environment,” “virus,” “COVID-19,” “air quality,” “aquatic life,” “wastewater quality,” “environmental impact assessment,” “environmental pollution,” which were combined with the Boolean search words such as “AND,” “OR,” were used. Selected articles within the last 16 years (2004–2020) were filtered and streamlined based on relevance to subject matter and thoroughly studied to arrive at major themes that have been sectioned and elaborately discussed in this write-up. Other non-environmental impacts of COVID-19 were not considered.

Themes discussed in this chapter are the effects of COVID-19 on socioeconomic development, environmental management for COVID-19 transmission, environmental impact assessment of COVID-19 pandemic on global physical environment, air quality, environmental pollution, water resources and aquatic life, ecological parameters and soil systems, noise pollution, increased solid wastes and recycling, wastewater quality and sanitary systems, correlation of temperature with COVID-19, and other indirect effects of COVID-19 on the environment. A table of full library search of recently published papers in reputable journals with their concise findings within the scope of this chapter has been presented, and the conclusion was presented.

13.3 Effects of COVID-19 on Socioeconomic Development in the Environment

The assessment of the consequential effects of COVID-19 on socioeconomic development poses a very herculean task when adequate data are deficient and because each person responds differently to its effects. The socioeconomic parameters that are of great importance to the study include the household size, population density, rural and urban settings, level of education, people's lifestyle, tenants, and landowners. The size of a household greatly matters in the communal transmission of the virus. Large household members exhibit a higher tendency to contract and transmit the virus within their family setting than a small household. This is typical of large multi-generational homes that are prevalent in Italy and this explains one of the reasons for the outrageous morbidity and mortality rates experienced during the first quarter of the pandemic in Italy. It is also highly likely to witness infected people, who stay within the same neighborhood, to be adversely affected by the virus because the major means of transmission is via droplet contact from an infected person. Urban areas are noted for high population density, which increases contact and transmissibility. It has been recommended that special attention aimed at saving highly vulnerable populations, including children, healthcare workers, and older people be put in place to contain the transmission of COVID-19 in socioeconomically – disadvantaged settings [16].

Social distancing etiquettes are met with sheer defiance and lawlessness in most urban areas and large households, thereby promoting the transmission of COVID-19. Working remotely from home is negatively affected when smaller and more crowded homes are in use. Each occupant fights for limited space and ends up with no buffer zone for contamination protection since droplets fly around within such a small apartment. Human beings' disposition to smoking and other dangerous lifestyles increase their level of susceptibility to infection by the virus. Smokers are greatly at risk as a result of the apparent effects of smoking on the lungs, and this practice is predominantly in lower socioeconomic settings [17]. It has also been recorded that people with underlying medical conditions such as chronic respiratory diseases, cardiovascular diseases, diabetes, cancer, or high blood pressure are at a greater risk of COVID-19 [17]. Another perspective is the unfortunate reality that different socioeconomic groups have different access to the same healthcare services, with reasons bordering on illegal immigrant status, uninsured citizenship status, relative inaccessibility due to poor roads, and sheer disenfranchisement of right to good medical healthcare as a result of huge medical bills. This is a typical phenomenon prevalent in Sub-Saharan Africa and, of course, a worrisome field of study.

13.4 Environmental Management as an Important Factor for COVID-19 Transmission

The untoward modern lifestyle that encourages the construction of mega-cities, proliferation of slums, excessive deforestation, degradation of aquatic life, erratic

exploitation of natural resources, desert encroachment, and heavy industrial emission have greatly affected the natural environment [18]. These activities created an artificial environment that offers a convenient platform for viruses, diseases, and poor sanitation to thrive. Through the principle of ecosystem services, environmental management offers a harmonious synergy in regulating water, air quality, pollutant purification, pest or disease control, and climatic condition [19]. Poor ecosystem services approach generates poor environmental management and inhibits biodiversity [19, 20]. Scientific findings have affirmed that the interaction between animals and man promotes pathogenic activities [21]. Enteric viruses have evolved such that they do not cause fatal health effects to the original host except secondary hosts to ensure continuity of life cycle and transmission dynamics [22]. With proper ecosystem services approach, efficient management of the natural environment and consequential reduction of negative anthropogenic effects are feasible to prevent the transmission of viruses by disallowing pathogens from leaving their natural environment and original hosts, with which they share symbolic co-evolution relationship. Table 13.1 shows a list of recent research findings on the effects of COVID-19 on the environment. These findings are fully explained in Section 13.5, while solutions and recommendations are presented afterward.

13.5 Environmental Impact Assessment of COVID-19

13.5.1 Environmental Variables Related to COVID-19

The spread and case fatality of COVID-19 have been reported to be greatly influence by environmental variables, including temperature, humidity, precipitation, particulate matter, and solar radiation [42–46]. Perone [42] found a correlation between COVID-19 mortality and some selected environmental variables including relative humidity and air pollutant concentrations such as NO_2 , O_3 , and particulate matters (PM_{10} and $\text{PM}_{2.5}$) in Italy. Temperature, solar radiation, and specific humidity were reported as the most relevant variables relating to COVID-19 in the Iberian Peninsula, with observed reduction in O_3 [43]. Ahmed and Ghanem [47] also noted a good link between precipitation and COVID-19 infection by relating it to a possible increase in the humidity of the ambient air and/or movement of the virus via environmental compartment by the running water. The particulate matter could serve as a safe haven for SARS-CoV-2 because of its complex mixture of fine particles, polycyclic aromatic hydrocarbon (PAH), and other organic matters by extending the virulence of the virus in the environment [44]. Rosario et al. [45] reported that the main environmental factor responsible for the suppression of the COVID-19 spread in the state of Rio de Janeiro in Brazil. There were also considerable impacts of COVID-19 measures on the environment and its variables. The major environmental variable that has received significant attention relating to the spread of COVID-19 pandemic is temperature, especially because of the wide gap of number of COVID-19 confirmed cases among the regional climatic conditions [46–48].

Table 13.1 Recent studies on COVID-19 impacts on the environment.

S/N	Authors	Findings (effects of COVID-19 on the environment)
1	Riou and Althaus [7] and Phan et al. [23]	• Aerosols affect human respiratory system via oral and nasal ingestion
2	Saadat et al. [16]	• Smoking and dangerous lifestyles increase the risk of contracting COVID-19
3	Zheng et al. [17]	• People with underlying medical conditions such as cardiovascular diseases, diabetes, cancer, etc., are at a greater risk of viral infection
4	Lal et al. [24]	• Air quality in New York greatly increased COVID-19 infection
5	Cheval et al. [25]	• Hypothesis stating pollutants as COVID-19 carriers is not found yet and that points of infections having similar demography, population density, and economic properties may experience similar viral infection and transmission curve – a typical case of Lombardy and Veneto regions in Italy
6	Adelodun et al. [26], Medema et al. [27], Gormey et al. [28], Mohan et al. [29], and Espejo et al. [30]	• Identification of SARS-CoV-2 in domestic sewage and wastewater has been documented and preventive measures such as ozonation, chlorination, and UV radiation technologies of water treatment for isolation holding facilities were suggested • Human enteric viruses have been spotted on surface water, public water supply, freshwater, groundwater, and sediments except sludge and wastewater samples
7	Atalan [10], Medema et al. [27], Saadat et al. [16], and Zambrano-monserrate et al. [31]	• Indiscriminate disposal of plastics and PPEs (made of polypropylene) in waterbodies in China, United States, and Hong Kong, thereby creating a surge in water pollution indices • Hospitals in Wuhan, China, produced an average 240 metric tons of medical waste per day during the pandemic as compared to their previous average of fewer than 50 tons pre-COVID
8	Núñez-Delgado [32]	• No scientific proof yet for the soil being a transmission medium for SARS-CoV-2
9	Chakraborty and Maity [33] and Zambrano-monserrate et al. [31]	• Drastic reduction in industrial wastes has been recorded in several countries as a result of lockdown • Sustainable waste management system is hampered by the use of single-use packaging since recycling programs are abolished
10	Wu et al. [34]	• A 1 $\mu\text{g}/\text{m}^3$ increase in PM_{2.5} generated an 8% increase in mortality rate in 3000 cities in the United States
11	Ogen [35]	• The long-term exposure of citizens of about 66 administrative regions in France, Germany, Spain, and Italy to nitrogen dioxide (NO₂) may contribute to mortality rate due to COVID-19
12	Xu et al. [36], Zhang et al. [37], Suhaimi et al. [38], and Pansini and Fornacca [39]	• Air pollution has improved transmission potential of COVID-19 • There is a direct correlation between air quality index (AQI) and confirmed cases of COVID-19
13	Zoran et al. [40] and Andree [41]	• Recorded new COVID-19 cases have a positive correlation with PM_{2.5} and PM₁₀ • PM_{2.5} was found to be an appropriate predictor of the number of confirmed COVID-19 cases

Source: Saadat et al. [16], Riou and Althaus [7], and Phan et al. [23].

Several researchers have made concerted effort in analyzing the connection between temperature and COVID-19 infection. There have been diverse submissions from highly reputable scholars about how temperature affects the trend of confirmed cases of coronavirus and vice versa. Some researchers believe that there is a positive association between temperature and number of confirmed cases, while some believe that the two parameters are negatively correlated. There is the third category of scholars who believe that there is no interaction between the two at all [49]. Temperature and humidity affected daily COVID-19 cases in 30 Chinese provinces and it was discovered that a 1 °C increase in average daily temperature reading reduced daily rate of COVID-19 cases from 36% to 57% at a relative humidity range of 65–85.5% [50]. Similarly, a 1% rise in relative humidity reduced daily COVID-19 cases from 11% to 22%, while the average daily temperature was within the range of 5.04 and 8.2 °C [50]. Gupta et al. [51] confirmed that humidity and temperature can forecast COVID-19 transmissions in the United States. It was suggested that the hot and humid climates in India might have played an important role in the low transmission of COVID-19. However, this hypothesis has been contested that strict and early lockdown was accountable for the low transmission rate and a future rise is expected owing to the inability of the citizens to sustain the lockdown practice because of high population density, proliferation of slums, and inadequate housing facilities [52].

Other studies on inter-relationship of temperature and number of COVID-19 cases have been exclusively argued by Xie and Zhu [53], Chin et al. [54], and Shi et al. [55]. There was a direct linear relationship between temperature and number of COVID-19 cases when the temperature was lower than 3 °C [53]. This was refuted by Shi et al. [55] that the opposite effects were experienced in China, where temperatures about the range of 8–10 °C reduced daily transmission of confirmed cases. Chin et al. [54] added that the virus is highly stable at 4 °C but sensitive to heat. A study in Spain concluded that there is an insignificant effect of temperature on the transmission potential of SARS-CoV-2 by using spatiotemporal modeling techniques and also introducing socioeconomic parameters such as age, population density, number of firms, and number of travelers.

13.5.2 Effects of COVID-19 on Global Physical Environment: Air Quality and Environmental Pollution

The effects of COVID-19 on the physical systems in the global environment cannot be overemphasized. These effects offer beneficial possibilities as much as disadvantages to all the parameters that make up the physical system. Air quality significantly increased the spread of COVID-19 infection in New York City [24]. The institution of lockdown measures has, in a way, underlined the need for effective population check in terms of density and measure. Urban areas are notable for their highly populated architecture and sparingly ventilated settlements. Lockdown practice in these areas may be faced with an increased risk in terms of exposure to hazards and threats. Highly dense areas with more aeration also increase the dependency on clean air, thereby creating an unhealthy rivalry among inhabitants. In rural settings where

there is proper ventilation and gardens, which ensure creation of clean air and scenic views, isolation measures are easily practiced with a net zero negative impact on the immediate physical system. Ordóñez et al. [43] carried out a study on the effect of strict lockdown measures (as a result of the first wave of COVID-19 in Europe) on air quality. They discovered that, within the study duration of 15 March 2020 to 30 April 2020, daily maximum NO_2 reduced consistently over the continents, with a reduction of 5–55% with respect to a base period of 2015–2019 for 80% of the study sites, with the highest reduction recorded in Spain, France, and Italy. Ozone concentration reduction was recorded in Iberia but increased elsewhere and was compared with expected NO_2 and O_3 concentrations in the absence of lockdown, using generalized additive models [43]. Their results pointed to the dominant role of meteorology on regional ozone anomalies in Europe during the lockdown and also determined ozone responses to emission changes or preferably, air quality. Also, there have been reported findings of a significant CO emission level of approximately 48.5–30.3% in Rio de Janeiro, Brazil [56]. Coal use in China caused a 25% reduction in CO_2 , which was equivalent to about 6% of global emissions [57], and 10 cities in China recorded a 20% reduction of $\text{PM}_{2.5}$ as a result of the pandemic [58]. Liu et al. [59] and Le Quéré et al. [60] reported some level of declining in country-level CO_2 emissions because of the energy consumption and human inactivity, especially ground transportation, as a result of lockdown measures imposed by each country to curtail the spread of COVID-19. About 9% global reduction of CO_2 emissions was reported for the first half year of 2020 compared to the year 2019 [59]. Table 13.2 presents the comparative assessment of CO_2 emission in some selected countries before and during the COVID-19 era.

It is a known fact that the level of air pollution of a typical area is an indication of the climatic condition of such a place and air pollution in the upward range may accelerate drastic changes in the ecosystem, thereby triggering pathogenic activity with increase in the outbreak of infectious diseases, vectors, hosts, and transmission dynamics [45, 46, 62, 63]. Hill [64] reported that pollutants such as organochlorines, organophosphates, heavy metals, carbamates, endocrine disruptors, dioxins, and methylmercury have greatly increased in concentrations and availability in the environment globally, as a result of anthropogenic activities and have been found in air, soil, water, vegetation, and animals. Furthermore, it has been reported that over 91% of the world population live in areas where poor air quality exceeds the allowable limits [65]. This finding has additionally offered a standpoint that inferred that air pollution contributes to about 8% of total global deaths, with the most badly-hit countries found in Asia, Europe, and Africa [65]. One of the response methodologies currently being practiced all over the world is partial/total lockdown, which has generated a reduction in carbon footprint in terms of greenhouse gas (GHG) emissions from manufacturing industries, aerosols, smoke emission from oil and its products' usage, and an obvious decline in nitrogen oxide (NO_2) concentration in European countries such as France, Germany, Spain, and Italy, as a result of anthropogenic-based activities. The pandemic has resulted into higher concentrations in atmospheric pollutants such as NO_2 , which has been linked with diseases such as bronchoconstriction, lung infections, reduced

Table 13.2 Comparative assessment of carbon emissions between pre-COVID-19 and post-COVID-19.

Region	Country	Population (millions) ^{a)}		CO ₂ emission (Mt per day) ^{b)}		
		2019	2020	2019 (1 January to 30 June)	2020 (1 January to 30 June)	% Reduction
North America	United States	329.06	331.00	2 543.61	2 205.31	13.3
Europe	United Kingdom	67.53	67.89	178.67	151.87	15.0
	Russia	145.87	145.93	764.15	723.65	5.3
	Germany	83.52	83.78	357.62	303.62	15.1
	France	65.13	65.27	151.41	129.91	14.2
	Italy	60.55	60.46	167.15	144.25	13.7
	Spain	46.74	46.75	122.87	99.77	18.8
	Japan	126.86	126.48	574.67	531.57	7.5
Asia	India	1 366.42	1 380.00	1 332.47	1 127.27	15.4
	China	1 433.78	1 439.32	5 059.46	4 872.26	3.7
South America	Brazil	211.05	212.56	215.83	189.93	12.0
Global	World	7 713.47	7 794.80	17 619.32	16 068.82	8.8

a) Worldometer [61].
b) Liu et al. [59].
Source: Liu et al. [59] and Worldometer [61].

immunity, and respiratory problems, thereby resulting in an increased susceptibility to colds and flu.

The effects of COVID-19 pandemic on air quality with respect to energy use, production and transportation companies, retail and personnel cannot be over flogged. A critical study of energy use for industrial and transportation purposes in European Economic Area (EEA) countries such as Norway, Iceland, and Liechtenstein showed that severe impacts on air quality were recorded in mid-April of the COVID-19 year, with about 40–50% reduction in economic activity [66]. This was as a result of strict COVID-19 protocols set in place to inhibit the transmission of the virus. Another notable effect of reduction of air pollution is the significant decline in global coal consumption, especially in China. Also, by the end of July 2020, there were reported reductions in air pollution in New York City, China, and Italy, and currently, there are predictions of declines in GHG emissions toward the end of the year [25]. However, it is imperative to know that the reduction in GHGs may offer an insignificant effect on total GHG concentrations, which have accumulated in the atmosphere for decades. The reduction may be temporal because once the pandemic ends, all countries may likely initiate extreme economic and industrial actions to resuscitate their economies, thereby increasing GHG emissions and reverting us to where we started or farther still.

The infection and mortality rates in Northern Italy became so worrisome that most researchers used the region as an epicenter case study for current and future research works. It is believed that the presence and subsequent inhalation of particulate matter such as PM_{10} and PM_{25} by citizens increased viral susceptibility of the respiratory systems of citizens even before COVID-19. So, when the coronavirus emerged, the elderly could not endure such viral load and yielded to the fatal tendency of the virus. Furthermore, it has been reported that there is a high level of correlation between COVID-19 viral spread and pollution levels [38], and even, further study has confirmed that stronger evidence abound on the idea that many COVID-19 patients in Italy were initially exposed to respiratory system threats and diseases. However, hypothesis stating pollutants such as COVID-19 carrier is not found yet [25].

Also, Cheval et al. [25] submitted that the two Italian regions (Lombardy and Veneto) that were mostly hit by COVID-19 shared a similar architecture in terms of demography, population density, and economic properties. Cheval et al. [25] feel that the two regions share these similar traits and that it is only logical that they experience similar COVID-19 adverse effect as a result of similar population densities within the range of 270–420 per km^2 ; gross domestic product of Veneto of £29 500/capita and Lombardy of £34 000/capita. Definitely, COVID-19 varies spatially.

13.5.3 COVID-19 Impacts on Water Resources and Aquatic Life

Lockdown activities have generated a great reduction in aquatic transportation and tourist activities; however, there is the worrisome report about increased disposal of sanitary items especially personal protective equipment (PPE) in open waterbodies.

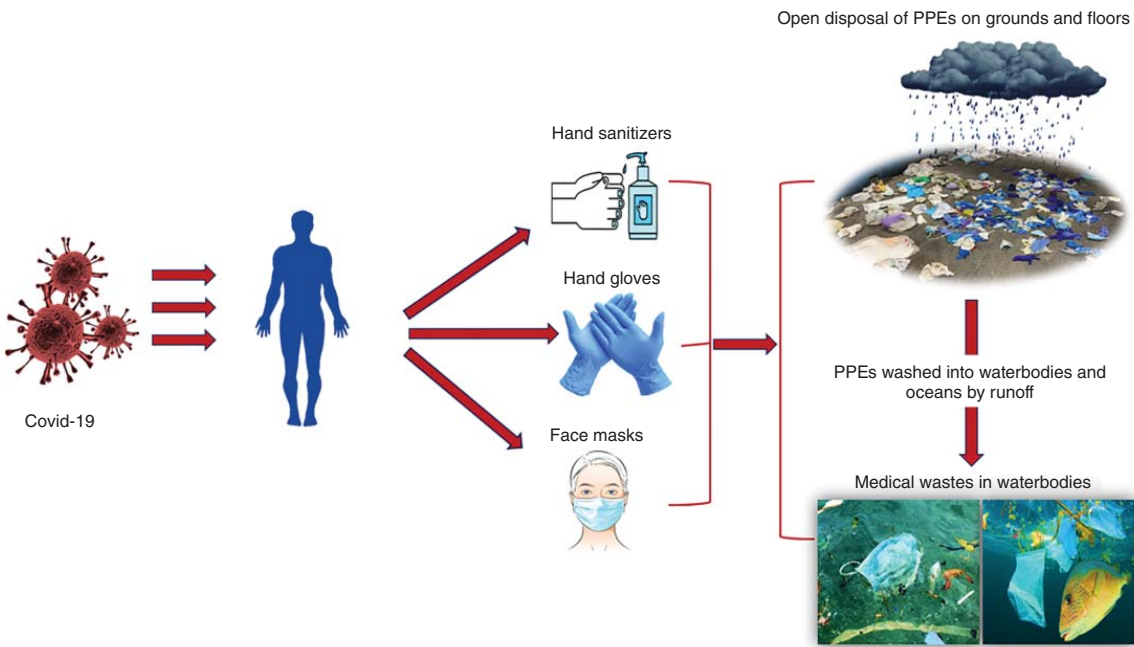


Figure 13.2 Medical wastes created during COVID-19 pandemic.

This may harm aquatic life and threaten the growth of riparian vegetation along water courses. Indiscriminate disposal of plastics and PPE have been reported in Canada, the United States, and Hong Kong [10, 27]. Plastic pollution of waterways was recorded in China where plastic-made medical masks (made of polypropylene) were collected from the sea by some environmentalists and concluded that COVID-19 measures created a surge in water pollution indices [27]. COVID-19 impacts on water resources may create a long-term impact with respect to depleting national reserves and nose-diving revenue generation status of every single country. Figure 13.2 shows the illustration of medical waste generation (PPE) during the pandemic.

In contrast, one of the beneficial effects of the pandemic on waterbodies as a result of lockdown was recorded in Venice, Italy. Water obtained from canals in Venice was cleaner and less turbid as a result of lesser or no tourist usage of waterbodies, lesser sediment agitation, and reduced water pollutants. The water was clean and aquatic life could be assessed visually.

Restriction of movement globally has generated more pressure on demand and supply of water for domestic use. In Austria, daily peak water consumption in the morning had skyrocketed from about 1.5 to 2 hours. The water authority had to compensate for this surge by increasing the supply and a normal curve of transactional econometrics was observed afterward. Industrial water consumption has drastically reduced because of the mandatory lockdown and work from home practices. Water management for agriculture must be centered on efficient and sustainable use of water resources during post-COVID-19 era. This will ensure the gradual recovery of water resources that have been lost during the pandemic.

13.5.4 COVID-19 Impacts on Ecological Parameters and Soil Systems

The soil offers a medium for the growth of food and food materials. The effects of COVID-19 on soil resources may not be too obvious in the short term for now; however, isolation and lockdowns have denied farmers access to soil and agriculture. National food supply grid has been greatly affected and every nation's economy is currently bearing the brunt. Available food and crops are becoming unbelievably limited and inflation of prices of commodities has become the order of the day in Sub-Saharan Africa. At the moment, there is no proof to confirm that the soil environment may host and transmit the virus as do solid surfaces and metal surfaces [32].

The effects of COVID-19 on the ecological systems cannot be overemphasized. The prevalence of the virus may pose greater threats to our society in years to come because the virus may eventually have an indirect effect on the climate change on the ecosphere. These effects may include changing species, alien invasion, and diminishing species habitat. There may also be an economic effect on conservation programs and ecology-oriented research globally, as funding for research deplete daily and people are only worried about their safety/survival than proffering solutions to the current situation.

13.5.5 COVID-19 Impacts on Noise Pollution, Increased Solid Wastes, and Recycling

During the lockdown, beaches and recreational centers were deserted, indicating a reduction in waste load generated by tourists and a significant noise reduction due to non-patronage of mass transit/public transportation systems, which may increase the transmission risk of COVID-19. Industrial waste emission has drastically reduced as a result of closure of industrial activities [33]. Gradual ease of lockdown protocols has required some firms to institute COVID-19 work ethics – one of which requires the repeal of disposable bags and containers while embracing single-use packaging and online ordering of necessities in order to reduce transmission [31]. As much as this offers a preventive approach to transmission and infection, however, it still poses a negative effect on people as recycling programs are being suspended and sustainable waste management is greatly inhibited.

The implementation of lockdown measures has resulted in the generation of increased demand for online orders for groceries and domestic supplies all across the world. This has created an enormous organic and inorganic waste overflow from households. Inorganic wastes are also generated from packaging packs of food supplies ordered on the internet and shipped to point of delivery by individuals or drones. Hospitals in Wuhan, China, have been reported to produce an average 240 metric tons of medical waste per day during the pandemic compared to their previous average of fewer than 50 tons post-COVID-19 era [31]. Water treatment plants in China have been enjoined to fortify the disinfection unit operation by increasing the dosage of chlorine with a view to preventing the spread of COVID-19 through wastewater, even though there has not been any verified reported case of COVID-19 transmission through wastewater [67].

13.5.6 COVID-19 Impacts on Wastewater Quality and Sanitary Systems

There have been reported cases of identification of SARS-CoV-2 in domestic sewage, and this has propelled the need to create life cycle assessment of the virus especially as it passes through waterbodies [26, 27, 68]. This potential transmission of the virus through wastewater is currently generating a growing concern in research areas of epidemiology, public health, wastewater engineering, and virology [69–71]. The possibility of transmission of SARS-CoV-2 through water infrastructure was reported to be a major concern, and its detection and subsequent inactivation will play a major role in curbing the spread of the virus to the community [29]. Furthermore, the detection of the virus in wastewater when the SARS-CoV-2 count was low indicated the functional role of wastewater monitoring, in order to assess the spread of the virus [29]. It has also been reported that human enteric viruses have been observed on surface water, groundwater, public water supply, freshwater, and sediments aside sludge and wastewater samples [1, 28, 29]. Recent studies have concluded that there are significant viral loads of SARS-CoV-2 in human feces from infected persons with severe symptoms [55, 56, 72, 73]. During conveyance of wastewater containing human excreta, there may be leakages in sewerage systems, thereby increasing

the risk of sanitation-related diseases to man [27, 28, 74]. There is an urgent need to proffer proactive solutions to stem the transmission dynamics of the virus via contaminated wastewater. Adelodun et al. [26] highlighted several solutions to potential wastewater infection by SARS-CoV-2 especially in isolation homes, treatment facilities, slums, and low-income countries. Solutions proffered included decentralization of wastewater treatment facilities, practice of community – wide monitoring and testing of SARS-CoV-2 RNA in wastewater, improved sanitation and water quality by embracing ozonation, chlorination, and UV radiation operations in wastewater treatment plants, and enhanced policy intervention. These measures centered on instituting policies that will mitigate the communal outbreak of SARS-CoV-2 from waterbodies and streams, which serve as a primary source of water consumption and for bathing, to inhabitants of villages in low-income countries [26, 75, 76].

13.5.7 Socioeconomic Environmental Impacts of COVID-19

The event of COVID-19 has greatly altered the social, economic, and environmental indices, in which the impacts vary across the countries, sectors, and domains. For instance, although countries such as France, Germany, and the United Kingdom mandated the second lockdown because of the recent rising cases of COVID-19 [77], the majority of the countries in Africa and Asia are full of economic activities with only measures of face masking in public places. Similarly, the transportation sectors such as aviation and road transportation were found to experience significant decline because of the imposed lockdown measure in India, China, and the United States [59, 78]. Before the emergence of COVID-19, there was socioeconomic and environmental inequality among the citizenries in each of the countries [1]. The various measures to mitigate the spread of COVID-19, such as human and vehicular movement restrictions and the shutdown of industries, further aggravate the impacts of the socioeconomic activities and productivity of the people, the majority of which are from less-developed and developing nations [79]. Although there were some reported positive impacts gained from imposed human inactivity measures to address the COVID-19 spread, particularly from the environmental perspective such as pollution and CO₂ emission reductions [59, 60, 79], the global economy is, however, greatly impacted as indicated by the report from the International Monetary Fund of possibly 3% decline in the economic growth [80]. This indicates that the measures to combat the spread of COVID-19 have somewhat favored the reduction in environmental pollution at the expense of socioeconomic retrogression [2]. However, many countries have instituted economic assistance in monetary stimulus packages for their citizens [2]. The economic intervention also dubbed as social intervention programs in some countries [81].

13.5.8 Indirect Effects of COVID-19 on the Environment

The lockdown has reduced the number of tourists visiting natural parks and other attraction centers, thereby reducing stress on wildlife [82]. Wild fauna have started encroaching and migrating back to the suburbs from which they had initially fled.

Forest reserves and wildlife policies should be implemented and focused on protection of wild animals and abolishment of indiscriminate hunting in less-developed countries after this COVID-19 era. In addition, there is a recorded global increase in solid wastes generated domestically and industrially as the lockdown relaxes and normalcy is being restored gradually. A few countries have resorted to a less sustainable approach of incinerating PPEs and contaminated medical wastes obtained from testing and isolation facilities in order to exterminate the virus, thereby affecting public health, soil life, water resources, and depleting the ozone layer [83–85]. Further harmful effects of this disastrous practice may result in unfavorable climate change, buildup of GHGs, acid rain, reduction in soil fertility, and poor agricultural produce. Since the wastes are biodegradable and the soil environment has not been proven to be a transmitting medium for SARS-CoV-2, it is recommended that such wastes should be decontaminated and used as landfills or compost for future agricultural use. The use of hand sanitizers is a common practice in this COVID-19 time and it is composed majorly of alcohol and a universal antimicrobial drug called Triclosan, which is tagged an emerging contaminant [86]. Too much use may create harmful effects on public health and environment.

Pérez-Espejo et al. [87] recommended the employment of Information and Communications Technology (ICT) knowledge in curbing the menace that comes with inaccessibility of data relevant to indoor air quality indices and human health as a result of lockdown and isolation. They concluded that the use of “smart home,” “smart care,” and “health monitoring gadgets” will go a long way in collating and analyzing meteorological data which affect the spread of the pandemic. Some developed countries such as the United States, South Korea, Japan, and Malaysia have health monitoring mobile applications that monitor COVID-19 symptoms of people. Travelers are subjected to COVID-19 testing and the mobile applications are installed on devices to monitor health progress of such people. This approach is safe and ensures less or no contact with potential COVID-19 victim, thereby reducing risk of infection, physical stress that comes with traveling to assess the travelers, and improving mental health of frontline workers in hospitals and holding facilities. Other indirect effects of COVID-19 pandemic on the environment include noise reduction, less turbid and cleaner waterbodies, cleaner air, etc. All these have been thoroughly explained in Section 13.5.8 of this book chapter.

13.6 Conclusion

This book chapter has taken a holistic approach in analyzing the effects of COVID-19 on the environment by taking a broad look at all environmental parameters as they affect the transmission potential of COVID-19 in the environment. The environmental effects of COVID-19 has cut across all phases of life and created a resonating effect on economy, sociocultural lifestyle, water resources, public health, many more. This unprecedented pandemic has unequivocally taught us a lesson of a lifetime and a need to further approach goal-driven research, regular climate change assessment, worthwhile economic surveys, forecasts, and sustainable ecosystem services, in a bid

to creating a better world and an ever ready approach to survival. A proper evaluation of interrelationship and correlation of key meteorological parameters as they affect the transmissibility of COVID-19 and other respiratory viruses will go a long way in reducing the rapid infection by corona virus and providing a reliable viewpoint in formulating well-informed prediction policies of the effect of pollution and weather data on the transmission potential of viruses. All these can be set in motion while we anticipate the discovery and manufacturing of COVID-19 vaccines.

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