Chapter 15
COVID-19 Pandemic: An Unprecedented Blessing for Nature

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Abstract  Nature has the remarkable ability to replenish and self-purify overtime; however, imprudent human activities have slowed down the ecological reconditioning functions. Degradation of air, water and soil, destruction of natural habitat, and compounded loss of floral and faunal diversity has been a major cause of worry among environmentalist. Measures adopted to address these issues have not yielded result on expected lines. But the year 2020 turned out to be a blessing in disguise for the environment. The COVID-19 quarantine lockdown has restricted people to home and brought human activities to a halt; thus, giving an edge to the natural resources to replenish themselves or the freedom of movement to animals in human-dominated lands. Scientists from diverse fields are trying to explore and validate the lockdown impact on ecology through proper scientific methods and data interpretation. This chapter mainly reviews the various studies carried out globally to assess the effects of the lockdown on the ecology and natural resources. An attempt has been made for a detailed and retrospective discussion on the effects of lockdown on the environment and the measures to be adopted for sustenance of ameliorated state of ecology along with economy revival. Most of the research articles affirmed the positive impact of the quarantine lockdown on ecology. The Earth’s ability to recover its health in such a small period leaves us with a question of why humans, the so-called a superior intelligent organism, cannot effectively manage the only habitat in the universe?

Keywords  COVID-19 quarantine · Monitoring of ecology · Improved air quality · Cleaner water bodies · Biodiversity
15.1 Introduction

Pandemics such as the Spanish flu, Black Death (Plague), Tuberculosis, Cholera and Acquired Immune Deficiency Syndrome (AIDS) have been a part of human history since very early times. The term pandemic (derived from the Greek word pan meaning all and demos meaning people) is a large-scale rapid outbreak of an infectious disease that can spread over a wide geographic area causing increase morbidity and mortality. Various studies have predicted that the increased global integration, urbanisation, and exploitation and disruptions of the natural environment are the cause behind the increased and intensified trend of pandemics in the past few decades. Since the year 2000, a number of disease outbreaks such as Severe Acute Respiratory syndrome (SARS) 2003, Influenza 2009, Ebola 2013, and Zika 2015 are witnessed. International and national communities have made substantial progress in the preparedness and mitigation of pandemic impacts, but the emergence of the most recent 2019 coronavirus attack has unveiled the existing significant gaps and challenges in global pandemic preparedness. The on-going global pandemic Coronavirus disease 2019, better known as COVID-19, is an infectious disease caused by Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2). It was first identified in December 2019 in Wuhan, Hubei, China. The World Health Organization (WHO) announced COVID-19 as a global pandemic on 11 March 2020 as the disease rapidly spread from China to South Korea, Japan, Italy, France, Spain and the United States. According to WHO statistics, more than 16 million cases have been reported across 216 countries and territories, resulting in more than 662,095 deaths up to 31st of July 2020. While scientists indulge themselves in vaccine preparation, the most effective way that we can look upon for its control is quarantine or in softer sense social distancing as the virus primarily spreads between people during close contact. As countries go under lockdown, to stop the virus proliferation, there has been a positive realisation regarding the importance of personal hygiene maintenance, adoption of healthy lifestyles, better family interactions, vital role of doctors, medical workers and scientific researchers, and the need for significant investments in the field of research and facilities. The influence of on-going COVID-19 lockdown encompasses various sectors. The six main quarantine impacts which are interlinked to one-another are Social, Political, Health, Economy, Research, and eDucation (SPHERED) (Fig. 15.1).

However, in this chapter, we are concerned mainly with the impact of lockdown on the environmental sector. Since the dawn of the industrial revolution in the eighteenth century, the influence of anthropogens on the four divisions of the environment-atmosphere, hydrosphere, lithosphere, and biosphere has been dramatically significant. The environment has drastically witnessed from small and scattered impacts to larger negative impacts. Consequently, the depleted quality of air, water and land, and degraded biodiversity is also slowly and progressively affecting human life in a negative way. The mere fetish for consumption of exotic meat i.e. meat of wild animals, not only threatens the loss of biodiversity but also causes spread of fatal diseases such as Ebola virus from animals to humans through bushmeat. Experts claim that
annually six million tons of bushmeat (orangutans and chimpanzees) are taken from the Amazon and the Congo Basin. Today people are bared to various waterborne diseases (cholera and typhoid), respiratory problems, and harmful effects of metal bioaccumulation. Statistics reveal an annual death of 2.4 million people prematurely due to air pollution or 3–4 million deaths due to waterborne diseases [1, 2]. Earlier it was believed that human presence on Earth was insufficient to affect the natural world [3]. But in the last two centuries the growing human development activities such as fossil-fuel combustion, infrastructure development, urbanisation, agriculture and waste generation has degraded the natural environment. Reports such as a two-fold surge in greenhouse gas emissions, change in atmospheric composition, the occurrence of brown or grey polluted skies, increase in percentage of disturbed Earth’s land surface and surface water area, conversion of wetlands, grasslands and forests to agricultural fields and urban areas, and roughly 1 million plant and animal species including almost a third of coral reefs, 40% of amphibians, more than one-third of marine mammals and 10 per cent of all insects at risk of extinction, depicts a grim future of the planet. The anthropogenically elevated and created environmental problems have disrupted the natural processes of ecology to such an extent that nature’s remarkable ability to replenish and self-purify have been slowed down and impaired. As such the on-going global pandemic turns out to be a favourable situation for the environment unlike the human population which is struggling to survive.

Fig. 15.1 Six major impacts of COVID-19 lockdown—Social, Political, Health Environment, Research, Economy, and Education (SPHERED)
against the disease. The quarantine restrictions on social gatherings and community mobility have resulted in the halt of world economies due to the discontinuity in industrial activities, tourism, travelling, transportation, and other commercial activities such as the closure of construction work, hotels, restaurants, shopping malls and cinema halls. The April *World Economic Outlook* estimates the global growth to fall to three per cent by 2020 [4]. The end of March 2020 witnessed a recession in the global aviation activity and transport activity almost by 75% and 60%, respectively below the 2019 average [5]. In the first quarter of 2020, a projected decline of 57 and 2.5% in the global oil demand and electricity demand, respectively is expected. Full lockdown in places like India, the US northwest, France, Italy, Spain and the United Kingdom led to a reduction in the daily electricity demand by at least 15%. Thus, the quarantine lockdown indeed has been a blessing in disguise for Mother Nature by giving her the time to heal from the damages caused by anthropogenic activities. With the cease of human activities, there are media reports of improved air quality, cleaner water bodies, and sightings of wildlife in the contested habitats. The speculations were validated by numerous scientific studies which evaluated the impact of quarantine lockdown on the ecology by assessing the air quality, water status and biodiversity [6–9]. On reviewing the articles on the impact of lockdown on ecology, it is observed that the highest number of studies was carried out on air quality status [6, 8, 10]. Even agencies such as the United National Aeronautics and Space Administration (NASA), European Space Agency (ESA) and Centre for Research on Energy and Clean Air (CREA) has reported on the status of air quality in various parts of the world by assessing the decreased nitrogen dioxide emissions in countries like China, Italy and Spain. Comparatively, fewer research articles [7, 11] were found on assessment of water quality and biodiversity because of the probable reasons such as restriction on the field sample collection amidst lockdown and limited access and expertise to GIS technique.

The chapter is an amalgamation of many globally reported data on the positive and negative impacts of the lockdown on the air, water and biodiversity. The chapter thoroughly reviews and assesses the monitored parameters of air and water, and also provides an in-depth and comprehensive description of how the influenced parameters during the restricted human activities ultimately improve the overall quality status. It also discusses the measures for revival of environment and economy, and the shortcomings such as the need for more studies on secondary air pollutants, water parameters and biodiversity in conditions when minimum human interventions prevail. The sudden positive changes in the quality of air and water and also behaviour of wild animals during the COVID-19 lockdown period is not a miracle. The worldwide reports on the reduced concentration of air pollutants, improved parameters of water bodies and sightings of wildlife moving freely in the human abandoned places are the reflectance of the positive changes that were obtained as a consequence of the COVID-19 restrictions on the movement and activities of humans. Thus, another contribution of the chapter is that it effectively reflects the positive impact of restricted or controlled activities of human on the environment in a short duration. The chapter compels the readers to contemplate that if restricted human actions for a short-duration can bring about such significant changes then
properly strategised measures for the environment will surely restore and sustain the nature on a longer run.

15.2 Impact of Quarantine Lockdown on the Ecology

Today, if one talks about the course of human development on Earth, the term pollution tags along with the revolution of food and machinery industries, science and technology, buildings and infrastructure, etc. It seems that whatever resources human has utilised for sustenance on the planet, each resource has suffered from degradation. With passing time, the list of devastation by human activities seems to keep growing in the form of air pollution, water pollution, light pollution, noise pollution and destruction of other life forms. In the twenty-first century, a sight of clear sky, a fresh clean wisp of air, crystal shining water, vastness of forests, whistling of birds, fluttering butterflies seemed to exist only as thoughts in people’s mind especially those living in the urban areas. Though numerous meetings, discussions, conferences, and mass awareness drives are periodically held around the globe to save the ecology and natural resources; however, insignificant outcomes, as compared to the expected results, were achieved in the end. But the year 2020 turned out to be a blessing in disguise for the environment as the quarantine lockdown gives time to our Earth to breathe again and replenish itself. The impact of quarantine lockdown is assessed by monitoring of the ecology which is discussed below.

15.2.1 Impact on Air Quality

A human can survive without water and food for a few days, but without air can manage to live only up to a maximum time of 3 minutes. The air that we inhale consists of nitrogen (78%), oxygen (21%), water vapour (varying from 0.01 to 4%), 0.93% argon, 0.039% carbon dioxide and trace amounts of dust particles as well as other gases including methane, nitrous oxide and ozone. Any imbalance (either increase or decrease) in the quantities of these air constituents or addition of other substances from human sources causes depletion of air quality. The degraded atmosphere can cause severe repercussion on human health without discriminating on the basis of gender, age and economic conditions. Even other living organisms whether flora or fauna (particularly aerobic life forms) are affected by the depleted air quality. Apte et al. [12] using data from the Global Burden of Disease project estimated a reduction in the average global life expectancy at birth by approximately one year due to PM$_{2.5}$ exposure in 2016. The monitoring of atmospheric composition and quality of air is given importance on the occurrence of an event at the regional or global level that may influence the ambient air status. Studies suggested a possible relationship between concentrations of air pollutants and risk of COVID-19 disease. Scientists worldwide are assessing the impact of ceased industrial and transportation
Air pollutants generated from natural and human sources fall under two broad categories, namely primary pollutant and secondary pollutant. Pollutants such as carbon monoxide (CO), carbon dioxide (CO₂), methane (CH₄), nitric oxide (NO), nitrogen dioxide (NO₂), nitrous oxide (N₂O), sulphur dioxide (SO₂), ammonia (NH₃), most hydrocarbons, and most suspended particles matter which are directly emitted into the atmosphere from their sources are called primary pollutants; whereas, the chemicals such as ozone (O₃), peroxy acetyl nitrate (PAN), hydrogen peroxide (H₂O₂), sulphuric acid (H₂SO₄), nitric acid (HNO₃) which formed by the reaction of primary pollutants with one another or other natural constituents of air are called secondary pollutants. Globally, most of these pollutants are regularly monitored and reported as they are extremely hazardous to living organisms. Apart from quantifying the concentration of pollutants and then comparing them to ambient air standards, the quality of air is also evaluated by application of different types of air quality indices such as Air Quality Index [13], Aggregate Air Quality Index [14], Common Air Quality Index [15], New Air Quality Index [16], Pollution Index [17], Aggregate Risk Index [18] and National Air quality Index [19]. Among these indices, the Air Quality Index (AQI) (US EPA) is the most commonly used index to denote the magnitude of air pollution of an area. AQI is based on the aggregation method where the AQI value is calculated using PM₁₀, PM₂.₅, SO₂, NO₂ and CO [20]. Based on AQI values, the quality of air is defined from good to hazardous/severe for human health conditions. Thus, lower AQI values (i.e., <100 is considered to be desirable for breathing) while higher AQI values > 100 denotes undesirable air conditions for breathing [21]. Studies by [8, 20–25] showed a reduction in the AQI values for northern China (8%), 366 areas of China’s mainland (20%), Wuhan (48%), Delhi (61%), Gujarat (32–75%), 22 cities of India (15–44%), and Lucknow (50–60%), respectively. A decline in the AQI values indicates an overall improvement in the quality of air during the COVID-19 lockdown period. The pollutants, which were mostly assessed and reported as indicators of quarantine lockdown impact on air quality, are in the order of their popularity in air quality studies oxides of nitrogen, particulate matter, oxides of carbon and SO₂.

15.2.1.1 Nitrogen Containing Species

Nitrogen is the most abundant element of the Earth’s atmosphere. It is also present in other forms such as N₂O, NO, NO₂ and NH₃. The oxides of nitrogen influences the Earth’s atmospheric oxidising capacity; while, NH₃ plays a role in neutralization of acid aerosols. N₂O, an important greenhouse gas, is about 200 times more efficient than CO₂ in absorbing IR radiation. This gas is emitted from undisturbed soils, fertilised cultivated soils, oceans, animal wastes, and burning of biomass and fossil fuel. N₂O is virtually inert in the troposphere and is depleted by the photochemical reaction in the stratosphere [3]. NO and NO₂ collectively designated as NOₓ enter the atmosphere from natural sources (lightning and biological processes),
and anthropogenic sources (fossil fuel combustion and biomass burning) [26]. When present in high concentration, NOx acts as a notorious air pollutant involved in the production and depletion of tropospheric and stratospheric ozone, and formation of photochemical smog such as PAN. NO2 is biochemically highly reactive and more toxic than NO, and can be very harmful to human and plant health. The estimated global emission of NOx by anthropogenic activities is approximately 53 million tons per year [6]. It is known to affect the plant growth and photosynthesis process and to cause respiratory ailments such as bronchial hyper responsiveness, cellular inflammation and respiratory problems in humans. As per various studies [27–30], the strict quarantine measures showed a positive impact on the air quality status at least from the perspective of reduced emission of oxides of nitrogen. The NASA and ESA data on reduced NO2 emission up to 20–30% is one of the first reports on the improved air quality in Wuhan, China, Spain, France, Italy and USA. The two space agencies using satellites AURA and Sentinel-5P, respectively, collected and compared the data for NO2 emission in 2019 and 2020. A large number of studies from China included reporting of reduced levels of different forms of nitrogen from places such as Shanghai (NOx 75%) [31], 366 urban areas of mainland China (NO2 54%) [25], Yangtze River Delta (YRD) region (NOx 29–47%) [32], 44 cities of northern China, Hubei province (NO2 25%) [8] and Wuhan (NO2 56%) [33]. Lian et al. [21] also found similar NO2 decreased percentage (53%) at Wuhan, and suggested the reduced NO2 concentration to be highly correlated with the reduction in traffic pollution at Wuhan during the lockdown period. Studies by [20, 22, 23, 34, 35] have reported the decreased NO2 concentration ranging 13–84% in the different cities of India such as Agra, Ahmedabad, Amritsar, Amravati, Ankleshwar, Bengaluru, Bhopal, Bhuj, Brijrajnagar, Chennai, Delhi, Dewas, Faridabad, Gandhinagar, Gaya, Hyderabad, Jamnagar, Jaipur, Jodhpur, Jorapokhar, Kanpur, Kolkata, Lucknow, Mumbai, Nagpur, Palanpur, Patna, Pune, Rajkot, Singrauli, Surat, Vadodara, Varanasi and Thiruvananthapuram. ESA also confirmed a drop in NO2 levels by around 40–50% in cities of India owing to its nationwide quarantine (Fig. 15.2). The agency also reported a decrease in the NO2 level in the maritime route across the Indian Ocean due to less maritime traffic [36] (Fig. 15.2). Kanniah et al. [37] used the Aura satellite sensor to monitor NO2 fluctuation, and reported a decreased NO2 concentration over other South-Asian cities such as Manila (34%), Kuala Lumpur (27%), Singapore (30%), Bangkok (22%), Jakarta (34%) and Phnom Penh (6%). However, the study found an increased NO2 concentration by 1% and 3% in Ho Chi Minh City (Vietnam), and Yangon (Myanmar), respectively. This increased NO2 levels were attributed to the high biomass-burning activity over the South-east Asian region along with several other influential factors such as meteorology [37]. A recent data released by ESA suggested that continuous lockdown measures in Europe have further lowered the levels of NO2 by 45–50% in Barcelona, Madrid, Milan, Paris and Rome (Fig. 15.2). Studies by [38, 39] concurred with the ESA observation for Milan, Madrid and Barcelona as the NO2 concentration ranged between 48 and 62%. Reduction in the NO2 levels by 35, 51, 54 and 96% was also reported for Kazakhstan [10], New York (USA) [40], Sau Paulo (Brazil) [41] and Morocco [42], respectively.
Fig. 15.2 Compared NO$_2$ levels between same periods of 2020 and 2019 in a France b Europe c India d Maritime route in Indian Ocean. In each inset the dark and light or faded tone represent higher and lower concentration of NO$_2$, respectively (Source NASA and ESA)

15.2.1.2 Oxocarbon, Sulphur Dioxide and Ozone

Oxides of carbon are known as oxocarbons, which comprises of only carbon and oxygen atoms. The most common oxocarbons found in the atmosphere are carbon monoxide (CO) and carbon dioxide (CO$_2$). CO is a colourless and odourless compound, which is highly toxic to humans. Apart from natural sources (such as volcanic eruptions and bush fires), CO is also anthropogenically generated by incomplete combustion of carbon-containing materials. Its high affinity towards haemoglobin compound in blood cells leads to the replacement of O$_2$ by CO, which acts life-threatening to human beings. In typical urban areas, the localised atmospheric CO levels are around 10 ppm (parts per million) which is about 100 times higher than in overall Earth’s atmospheric CO level (0.1 ppm). On the contrary, the atmospheric CO$_2$ is an important infrared-absorbing greenhouse gas which plays a crucial role in maintaining the average temperature (−15 °C) of the Earth for sustenance of living organisms. Nevertheless, immoderate anthropogenic activities such as clearing of forests and grassland, burning of fossil fuels, land-use changes, and vehicular and industrial emissions have increased the current CO$_2$ concentration to 412 ppm, which is 47% higher than the CO$_2$ level at the beginning of the Industrial Age [43]. Over the previous decade, the emissions of carbon dioxide have
been rising by about 1% per year [44]. Sulphur dioxide (SO\textsubscript{2}) is one of the primary forms of sulphur in the atmosphere other than dimethyl sulphide ((CH\textsubscript{3})\textsubscript{2}S) and hydrogen sulphide (H\textsubscript{2}S). SO\textsubscript{2} is a toxic gas produced during burning of fossil fuels and industrial activities. About 66.6% of SO\textsubscript{2} comes from human sources. Each year anthropogenic activities such as combustion of fossil fuels add approximately 100 million metric tons of sulphur to the global atmosphere primarily as SO\textsubscript{2} [26].

A reduction in the emissions of CO, CO\textsubscript{2} and SO\textsubscript{2} was also observed globally. Querre et al. [44] estimated that by early April 2020, the daily global CO\textsubscript{2} emissions have declined by 17%, when compared with the mean 2019 levels. A similar decline of about 1 million tons of carbon emissions (i.e. 25%) has been reported for China by Wang and Su [6]. The mentioned per cent decline in China is equivalent to 6% of global emissions over the same period. An overall reduction in the carbon footprint was observed between −5.6 and −10.6 Mt CO\textsubscript{2} (20%) during the lockdown in Italy [45] compared to the same period in 2019. A decrease in the concentration of CO and SO\textsubscript{2} was also observed in the lockdown. According to Wang and Su [6], China had an overall reduction of 6 and 21% for CO and SO\textsubscript{2}, respectively. A reduction in CO and SO\textsubscript{2} levels was recorded to be 22 and 15% for Shanghai [31], 23 and 4% for Wuhan [21], 5 and 7% for northern China [8] and 20% and 16% for 366 urban areas in China’s mainland [25]. Other countries which have a reported decline in these gases are Malaysia (CO 25–31%; SO\textsubscript{2} 9–20%) [37], Sao Paulo, Brazil (CO 65%) [41], Rio de Janeiro, Brazil (CO 30–49%) [46], Milan, Italy (CO 58%; SO\textsubscript{2} 25%) [39], Kazakhstan (CO 49%) [10] and Morocco (SO\textsubscript{2} 49%) [42]. Most of the studies in India showed a declining trend in the concentration of CO and SO\textsubscript{2} during the lockdown [20, 22, 23, 34, 35]. The levels of CO and SO\textsubscript{2} in some of the urban cities of India such as Bangalore, Chennai, Delhi, Gujarat, Mumbai, Nagpur were reduced by 24% and 81%, 24% and 69%, 30% and 18%, 25% and 40%, 46% and 47%, and 63% and 91%, respectively [20, 22, 35]. Navinya et al. [35] estimated the overall reduction for CO across the cities of India as 14%.

Another important pollutant that was monitored and documented in research articles is O\textsubscript{3}. O\textsubscript{3} is a compound which forms a protective shield known as the ‘ozone layer’ in the stratosphere. The layer screens out the harmful rays and ultraviolet radiations. However, O\textsubscript{3} formation in the troposphere acts as a nuisance pollutant which threat human-health (respiratory diseases), vegetation (destroys cell lining in plants) and materials [1]. Human sources such as industrial processes and vehicular emissions are the primary reasons for the formation of ground-level O\textsubscript{3}. Unlike the other major pollutants, O\textsubscript{3} showed an incrementing trend at places such as Brazil [41], China [31, 32], France [47], India [20, 22], Italy [39, 45] and Kazakhstan [10] (Table 15.1).

### 15.2.1.3 Particulate Matter and Aerosol

Apart from the gases, the Earth’s atmosphere also consists of various airborne microorganisms (bacteria and fungi) and particles such as dust, salt, soot pollens and ice. An aerosol is a suspension of solid particles or liquid droplets (or a combination
of both) in the air or any other gas. The suspended solid particles and liquid droplets are called as particulate matter (PM). The particles varying in size and composition; thus, range from being microscopic to aggregates of dust readily visible to the naked eye. The source of origin for atmospheric aerosols is either natural or artificial (human-made). Primary natural aerosol sources include sea spray emissions, volcanic emissions, mineral dust, while major anthropogenic sources include industrial and combustion emissions [3]. About 62% of the suspended particulate matter in outdoor air comes from natural sources, while the remaining 38% comes from human sources. Anthropogenic activities tend to contribute most of the smaller sized particles that have greater potential to cause damage to human health. Though these particles are small in size they can have a dramatic effect on the atmospheric chemistry by providing surfaces for heterogeneous atmospheric chemical reactions, attenuating actinic flux, acting as condensation nuclei. Thus, atmospheric particles influence weather phenomena, air quality and health of living organisms. These particles can corrode metals, discolour clothes and paints and can cause respiratory problems. In this chapter, we are concerned with particles classified as fine or PM$_{2.5}$ (with diameters less than 2.5 µm (µm$_{s}$)) and coarse or PM$_{10}$ (with diameters less than 10 µm$_{s}$) [3] because both the particles have been extensively monitored worldwide to evaluate the impact of quarantine measures on air quality.

According to Wang and Su [6], China showed a decline of 15% and 21% for PM$_{2.5}$ and PM$_{10}$, respectively. Other places of China such as Shanghai (PM$_{2.5}$ 33–44%) [31], Wuhan (PM$_{2.5}$ 37%; PM$_{10}$ 34%) [33], northern China (PM$_{2.5}$ 6%; PM$_{10}$ 14%) [8], YRD region (PM$_{2.5}$ 27–46%) [32] and 366 urban areas in China’s mainland (PM$_{2.5}$ 21%; PM$_{10}$ 27%) [25] also recorded a fall in the particulate matter concentration. Lian et al. [21] and Wang et al. [25] attributed the stoppage of construction and reduction in transportation and industrial activities as reasons behind the declined

| Study area | Ozone concentration | Reference |
|------------|---------------------|-----------|
| City of Milan, Italy | +252.3% | 39 |
| Almaty, Kazakhstan | +15% | 10 |
| India (22 cities) | +17% | 23 |
| Delhi, India | +0.78% | 22 |
| Gujarat, India | +58% | 20 |
| Singrauli, India | +35 | 34 |
| Rio de Janeiro | +67% | 46 |
| Sao Paulo | +30% | 44 |
| Yangtze river delta | +8–10% | 33 |
| 366 urban areas in China mainland | +59% | 25 |
| Wuhan | +116% | 21 |
| Nice, Rome, Turin Valencia, Wuhan | +(24, 14, 27, 2.4, 36%) | 47 |
particulate matter concentration. However, Chen et al. [31] state that the reduction in pollutant level (such as reduced PM$_{2.5}$ concentration) cannot be solely explained by alterations in primary emissions; instead, decreasing concentrations of nitrate (60%), ammonium (45%) and primary aerosols can also play an important role. In another study, the elements barium, copper, iron, potassium and zinc were found to be dominating PM$_{2.5}$-related elements [48]. The presence of these elements, even during the lockdown period at a rural site between Beijing and Tianjin was attributed to the aging processes of elements after the emission of fireworks in the Chinese New Year Eve night and vehicular emission [48]. A reduction in the particulate matter levels in other countries included studies by Abdullah et al. [49], Collivignarelli et al. [39], Kanniah et al. [37], Kerimray et al. [10], Nakada and Urban [41], Otmani et al. [42], and Zangari et al. [40] for Malaysia (PM$_{2.5}$ 58%), City of Milan, Italy (PM$_{2.5}$ 47%; PM$_{10}$ 48%), Malaysia (PM$_{10}$ 26–31%), Kazakhstan (PM$_{2.5}$ 21%), Sau Paulo state, Brazil (PM$_{2.5}$ 30%), Morocco (PM$_{2.5}$ 75%), and New York city, USA (PM$_{2.5}$ 36%), respectively. In contrast, a few studies [46, 50, 51] showed either a low reduction or zero reduction in the particulate matter levels during the lockdown phase. In India, maximum documentation [22–24, 34, 35] on the reduced levels of particulate matter during the imposed lockdown period were from Delhi. Sharma et al. [23] in their study monitored a total of 22 states of India and recorded the overall decrease of 43 and 31% for PM$_{2.5}$ and PM$_{10}$. They also observed a significant decrease in concentrations of particulate matter in north India. A similar observation was made by Navinya et al. [35], while examining the effects of quarantine lockdown on ambient air quality across 17 urban cities of India. Studies on reduced concentrations of particulate matter were also reported from Mumbai (PM$_{2.5}$ 37%; PM$_{10}$ 44%) [34] and Gujarat (PM$_{2.5}$ 38–78%; PM$_{10}$ 32–80%) [20]. On the other hand, an increment observed in the concentration of PM$_{2.5}$ (15%) and PM$_{10}$ (59%) in Singrauli was attributed to active operation of coal-based power station in the lockdown period [34].

There were also studies on aerosol optical density (AOD) for evaluating the quality of atmosphere. AOD is a measure of the attenuation of solar radiation due to absorption and reflection of incident light by the atmospheric airborne particles. AOD measurement is important for studying the impact of aerosol concentration on solar radiation, alterations in atmospheric phenomenon and human health. A reduced AOD value is an indicator of reduced aerosol concentration. NASA's Terra satellite captured the decreased AOD values over India and around the globe during the 2020 lockdown period (Fig. 15.3). A decline in AOD values were also reported for cities like Kuala Lumpur, Brunei, Singapore and Manila [37]. In 2020, Malaysia recorded an average AOD decrease of 57–72% as compared to the same period in 2019 [37].

Reports from worldwide showed the difference between the concentrations of air pollutants measured before and after impose of the lockdown restrictions. Several studies recorded the continuous decrease in the concentration of the air pollutants such as NO$_2$, SO$_2$, CO, PM during the complete lockdown period. The reduction in the amount of air pollutants in the atmosphere is only possible when the sources producing the air pollutants are curbed. The industries and motor vehicles are primary sources (i.e. causes direct emission) of many air pollutants such as NO$_x$, oxocarbons and PM. Thus, when human activities were restricted globally during the lockdown,
many industries and vehicular movement were ceased, which further resulted in lower emission of air pollutants. Similarly, the reduced aerosol concentration over India and Malaysia were due to the restrictions on certain human-made emissions which produce nitrates, sulphates, soot and other carbon-rich particles [52, 53]. The same declining trend was also expected for the measured O$_3$ concentration. Interestingly, the declining trend for O$_3$ was not observed for most of the studies [31, 39, 46] during the lockdown period, except by a few reports such as a study by Adams et al. [51]. They observed a reduction by 1.5–4.2 ppb in the atmospheric O$_3$ concentration of Ontario, Canada. At ground-level, the chemical precursors such as volatile organic compounds (VOCs) and NO$_x$ (emitted by human sources) undergo series of chemical reactions in the presence of sunlight to form tropospheric O$_3$ [25, 47]. NO$_x$ plays a vital role in the formation and destruction of O$_3$. NO$_2$ reacts with VOCs to form tropospheric O$_3$ while NO scavenges/consumes the O$_3$ compound [26, 47]. Also, PM acts as a sink for hydroperoxy radicals (HO$_2$) that are otherwise involved in the formation of peroxy radical-mediated O$_3$ production. Thus, the decrease in the NOx and particulate matter (PM) levels is attributed as the reason behind the surge in O$_3$ concentration during the control measures [41, 46, 47]. These studies revealed the impact of NO$_x$ and PM concentration on the concentration of O$_3$. Thus,
we need to understand that there is a need for further significant research for understanding/unravelling the behaviour of secondary pollutants in relation to multiple influencing factors such as changes in chemical precursors, reaction mechanism and meteorological parameters.

Deteriorated air causes morbidity and mortality among humans. Global report states air pollution as the fifth leading risk factor for mortality worldwide contributing to nearly 1 death in every 10 person [1]. In humans, air pollution is known to cause many long-term and short-term health effects such as asthma, cancer, cardiovascular mortality, chronic obstructive pulmonary disease (COPD), hypertensive disease, respiratory mortality, etc. [27, 54, 55] among humans. The relation between the inhaled quality of air and human health is so-well established that several air quality indices have been developed for evaluating the level of threat to human health based on the magnitude of air quality status. The recent improvement in air quality across many countries and regions due to the quarantine measures has paved the scope for research in better understanding of the effects of improved air on the mortality rate and risk to human health from COVID-19 disease. A study attributed the decreased air pollution as the reason behind diminished cause-specific mortality during the large-scale quarantine period in China [56]. They calculated that the declined concentration of daily NO₂ and PM₂.₅ pollutants, during the control measures, potentially avoided 8911 NO₂-related deaths and 3214 PM₂.₅-related deaths. There are also evident studies from London [28], California [57], England [58], Northern Italy [59] and USA [60] on the existence of significant correlation between the short-term exposure to air pollutants such as NO₂ and PM₂.₅ and COVID-19 disease cases and fatality rate. It is established that exposure to air pollution can compromise respiratory functions and therefore exacerbate the risk of contracting and dying from COVID-19 [60, 61]. Moreover, the adherence of the COVID-19 virus on PM could aid long-range transmission of the virus [62]. State of Global Air Report [1] states that in 2017 more than 90% of people worldwide live in areas exceeding the WHO Guideline for healthy air. Therefore, the need for adoption of better strategies and implementation of result-oriented policies is required to maintain the current temporarily improved air quality status on long-run basis.

### 15.2.2 Impact on Water Quality

Hydrosphere, which is one of the primary spheres of the Earth, covers 71% surface area of the planet. Major portion (97%) of Earth’s water is locked as salty oceans while the remaining percentage of freshwater comprises of polar icecaps, rivers, streams, lakes and groundwater. However, only about 0.024% is readily available for human utilisation. Historians have always acknowledged the close association of emergence and flourishing of civilisations with the existence of a nearby major water source such as River Indus (Indus Valley Civilisation) and River Nile (Nile Valley Civilisation), etc. Water has the unique ability to purify and replenish itself on Earth via various processes involved in the ‘hydrological cycle’. The quality and quantity of water has
been a key factor responsible for the sustenance of life and welfare of human beings. However, the increasing human population coupled with pollution, destruction of wetlands and forests, rapid urbanisation and industrialisation has altered hydrology and hydroclimatology. A quarter of the world’s population is already affected by water scarcity crisis; further, aggravation of the issue is predicted by experts [63]. ‘Day Zero’ situation in places like Cape Town, South Africa and Chennai, India are epiphany case studies regarding the indefinite withdrawal of water and poor management of water sources. Today most of the Earth’s water sources are facing the brunt of unchecked and escalated anthropogenic activities, and are being directly or indirectly polluted, physically altered (induced stratification in water bodies or acidification of ocean water) and destructed (by construction of dams). The World Commission on Water states that in the twenty-first century, 50% of the world’s 500 rivers are heavily polluted [2]. Pollutants such as heavy metals, pesticides, chemicals and by-products of industrial and mining activities, oil and oil by-products, organic pollutants, and radioactive substances are known to cause changes in water chemistry. Major anthropogenic sources of water pollution are improper disposal of solid-waste, burning of fossil fuels for energy and transport, entry of municipal wastewater and agricultural run-off, and discharge of industrial and domestic effluents. Industrial wastes and sewage alone pollute more than 66% of India’s water resources and 54 of the 78 monitored rivers and streams of China. Marine environment is also threatened due to large-scale dumping of untreated municipal (80–90%) sewage into oceans by most coastal developing countries and some coastal developed countries [64]. As such the quarantine lockdown provides a temporary relief to the aquatic ecosystems due to restricted human mobility. Reduction in solid wastes and effluents has caused rivers, lakes, and beaches to self-purify. Currently, literature regarding the impact of quarantine lockdown on the quality of water is very limited. However, those few studies have succinctly emphasised the positive impact of reduced human activities on water quality status. We found that during the COVID-19 restricted period, most of the research papers on improved water quality has been reported from India. River Ganga and River Yamuna are severely polluted water bodies of India. From late 1970s several research studies [65–70] have evaluated the water chemistry and the effects of anthropogenic activities on the both rivers. Though many initiatives in terms of policies and action plans have been taken up by the government and non-governmental agencies; nevertheless, optimistic results in the river water quality was not observed until now. Real-time water monitoring data study on Ganga demonstrated positive changes such as an increased dissolved oxygen (DO) and decreased biological oxygen demand (BOD), nitrate concentration, total coliform and faecal coliform count [71]. In fact, the alterations in the water parameters indicate the improved water quality of Ganga due to reduced industrial effluents and solid wastes disposal under lockdown restrictions. Other reported improvements in the water sources of India include Yamuna [72], Cauvery and its tributaries [73], and groundwater samples of a costal industrial city of Tuticorin in Southern India [74]. Apart from real-time monitoring, the remote sensing imaging techniques have also been used for assessment of prevailing conditions of water bodies. Satellite imagery revealed an improvement in surface water quality of Vembanad Lake [7] and
a lagoon of Venice [75], in terms of decreased suspended particulate matter. Restricted industrial activities under quarantine measures have also reduced the consumption of water by industries; thereby, reducing the industrial water demand stress.

Quarantine lockdown had an overall positive impact on water quality because several parameter values were either close or within the prescribed standards of pollution control agencies. However, there is a need for higher number of studies on the parameters of water for analysing and recording the impact of a period that has such minimal human and industrial activities. Quality water, sanitation facility and hygiene are issues which are mutually related to one another because accessibility to clean water source without improvement in sanitation and hygiene facility or vice versa is not possible. According to World Bank Group, 600 million people lack access to an improved water source and more than 1 billion people lack access either to improved sanitation or drink unsafe water from an ‘improved’ source. Unfit drinking water source and improper sanitation facility not only exposes a person to various health hazards but also acts as a primary cause for widespread of many communicable diseases. Reported development of ear infections, sore throats, eye irritations, respiratory disease, or gastrointestinal disease in people after swimming in coastal beaches in the United States is linked to transmission of vast colonies of viruses from sewage treatment plants to some U.S. coastal waters [76].

Though transmission of COVID-19 virus in humans is mainly airborne; however, transmission of SARS-CoV-1 virus via faecal-oral transmission and recent reports of SARS-CoV-2 viral shedding from the digestive tract (via stool) raised concern regarding possible transmission of COVID-19 virus through faecal-oral routes [77, 78]. Recent scientific studies [77–79] succinctly proved the persistence of SARS-CoV-2 virus loads in untreated wastewater and raw sewage for longer periods and its movement from untreated wastewater to river water systems. The loadings of COVID-19 virus from wastewater plants/sewer systems to ground or surface water sources further threatens human life. Thus, the COVID-19 pandemic further highlights the need for better sewer systems, proper functioning of wastewater treatment plants and access to safe and clean water.

### 15.2.3 Impact on Biodiversity

Biodiversity simply means variety of living organisms. It encompasses all life forms, present in the four spheres of the Earth, ranging from a microscopic bacterium to the massive Amazon forests or a big blue whale. Earth is endowed with a variety of ecosystem such as lakes, rivers, oceans, mountain, desert, forest, grasslands, wetlands which acts as home for various life forms. Earth’s every organism plays a crucial and specific role in the food chain (some are known to us while some functions are yet to be unravelled). Thus, when human beings destroy the habitat or kill other living organism relentlessly, it leads to chain of catastrophic imbalance in the ecology.
Further, pollution and climate change are indirect influence of humans on the survivalability of other organisms. As such, the biodiversity is declining rapidly in the millennium than it has at any other time in the anthropogenic history. Global risk report [63] states that already 83% of all wild mammals and half of plants are lost and further, an increment in the biodiversity extinction rate by approximately 1% per year is expected. Though plethora of environmental policies, conventions, conferences, and agencies exist for protection and conservation of wildlife and biodiversity; nonetheless, no other factor seemed to have such large-scale benefit to the environment except COVID-19 quarantine lockdown. Since declare of quarantine measures, tsunami of articles, pictures and videos regarding the visible impact on wildlife and biodiversity are out there in the media. Many scientists have also addressed the changes in the biodiversity due to lockdown [9, 11, 80–83].

Anecdotal reports on the impact of quarantine lockdown on wildlife, ecosystems and biodiversity have been extensively covered by many newspapers, articles and other electronic media. In the initial days of human confinement, some animals seemed under the pressure due to sudden disruption in human-animal interaction; while other species appeared to enjoy the freedom to move around boldly on land (terrestrial animals), water (aquatic life-forms) and air (birds) with minimised human interventions. In fact, Wildlife Institute of India launched an app ‘Lockdown Wildlife Tracker’ for convenient tracking of wildlife movements in human restricted zones and storing the data in the app for future scientific research, education and conservation purposes [84]. One more initiative taken during COVID-19 is the Bio-Logging Initiative which involves data collection on changes in animal movement, behaviour and activity using small electronic devices (bio-loggers) for research study [82]. Another positive impact has been the return and sightings of wildlife and aquatic organisms due to improved environmental conditions. Some of the narratives and video clippings include sightings of dolphins in harbour of Trieste, Italy, pumas in Chile, and successful recruitment of the critically endangered Olive Ridley sea turtles in India. Other positive impacts of restricted movement of traffic are reduction in killings of animals on roads and railway tracks, and reduction in risk to animals from traffic noise levels. However, the lockdown also had negative effects on the environment such as increase wildlife poaching incidents, food security of animals particularly urban dwellers at risk, the exploitation of resources such as forests and fishes [85], and difficulties in the quarantine of plant materials imported or exported for research purpose, which in turn may threat agricultural biosecurity [86]. Moreover, existence of baseless fear and lack of scientific knowledge regarding the COVID-19 virus among the administrative officials or public could pose threat to biodiversity. One such incident was recently featured on an article by Nature India which revealed that the administrative officials of Kashmir valley ordered the mass destruction of female poplar trees to curb further aggravation of COVID-19 related respiratory illness without any scientific consultation.

The quarantine period actually provided a silver lining as there were sightings and returning of many wild species of animals which were thought to be lost due to the human-induced changes in the environment. The COVID-19 lockdown period gives us a hope that if the quality of air, water and land is maintained by effective strategies
then we will be successful in saving many floral and faunal population and diversity. The reports on decreased risk to animal lives from noise pollution or restricted traffic movements (railways or rad vehicles) implies that there is a need to address the issue of ineffective drafting and documentation of ‘Environment Impact Assessment’ reports by the agencies, which often overlooks the impact of a construction (whether a track or infrastructure) on the biodiversity. The development of tracking systems for animals during the lockdown period will also aid in conservation and preservation of wildlife. However, more studies on biodiversity required to analyse the impact of lockdown in-depth.

Other miscellaneous impacts of the COVID-19 lockdown have been on noise pollution and waste management systems. Studies have appraised the reduction of noise levels due to reduced air, water and land traffic. Restriction on human mobility has reduced industrial wastes; however, large-scale generation of domestic wastes and medical wastes (personal protective equipment kits and testing kits) is still occurring. The possibility of spreading of the COVID-19 virus has discouraged the recycling and reuse of wastes; thus, increasing the pressure on the waste management system in various countries. Nevertheless, priority for proper disposal of wastes particularly medical wastes should be maintained to avoid secondary adverse impacts.

### 15.3 Measures for Revival of Environment and Economy

COVID-19 lockdown demonstrates that in the anthropocene period human is one of the chief drivers of environmental changes. The ceased human activities even for a few weeks made huge impact on the environment and other sectors. Globally, the lockdown period witnessed an improvement in the air, water and wildlife and biodiversity. The highly polluted air and water in several countries and regions before the worldwide lockdown period got significantly improved during the quarantine measures. Nevertheless, these ameliorated changes are temporary because as soon as human activities resume in the post-COVID period, the durability of the positive environmental changes is questionable. The high risk of COVID-19 morbidity and mortality in highly polluted regions even after having excellent medical facilities indicates that the development of an economy without a sound environment is not enough for the sustenance of the human race. Pandemic made us realise the need for focussing on strategies which will encourage preservation and conservation of the environment along with sustainable development of the society. Some of the measures which can be adapted to maintain the ameliorated state of ecology along with the revival of the economy in the post-COVID scenario are as follows:

(a) Adoption of more strict pollution laws and levying hefty fines and taxes on polluters.
(b) Policymakers should contemplate the efficiency of existing frameworks on the environment and reframe if required.
(c) In populated countries like India, a large number of private vehicles cause a greater amount of air and noise pollution. Thus, the government should encourage and provide more public transportation.

(d) The increment in ozone concentration even after curbing primary polluting sources implies the complexities involved with secondary pollutants. Thus, more scientific research, particularly on secondary air pollutants, is required.

(e) Boards and agencies on pollution control and biodiversity should be more vigilant.

(f) The demand for exotic meat not only puts pressure on biodiversity but also causes the spread of fatal diseases from animal to humans. Thus, there is a need for a complete ban on the illegal trade of meat and shut down of ‘wet markets’ along with strict vigilance by regional and international police officials.

(g) Country’s economy can be uplifted with priority given to local business and entrepreneurs by giving them incentives and recovery packages.

(h) Innovations and investment in sustainable infrastructure such as clean energy, lower energy consumption should be encouraged to reduce the carbon footprint.

15.4 Conclusion

The quarantine lockdown period has been a blessing in disguise for ecology and diversity. Still, we need to realise that this is only a temporary remedy to the various environmental issues. Presently, it is the time for the realisation of the importance of Earth’s natural resources and its proper usage because any environmental degradation acts as a feedback loop for the destruction of the human race. Economic development for humans is a necessity but not at the expense of nature should be a moral realisation and intelligent thinking of Homo sapiens (Frank Lloyd Wright- Study nature, love nature, stay close to nature. It will never fail you). The government, private companies, stakeholders and global and local agencies should focus on such policies and strategies which will allow a balanced revival of nature and economy at the same time.

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