



COVID-19: A pandemic that is intricately entwined with environment

Running Title: Impact of COVID-19 on and by the Environment

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This critical narrative review is intended to emphasize ecological issues related to the evolution of the novel coronavirus, the environmental factors associated with the disease progress, and the impact the pandemic is having on the environment. 60% of the emerging infectious disease of the last century (including deadly viruses like HIV, Ebola, Influenza, coronavirus strains like SARS, MERS) are linked to zoonotic spillover. Therefore, to escape the emergence of newer cross-species infections, proper precautionary measures should be taken. Every country has specific rules to deal with the biomedical waste produced in hospitals. But the COVID-19 pandemic has posed a unique global challenge due to the overwhelming amount of biomedical waste generated from dedicated COVID hospitals, diagnostic facilities, quarantine centers, and home quarantine facilities. Moreover, inappropriate disposal of masks and other protective gears by the general public may contaminate the environment turning it into a potential health hazard. Therefore, strict adherence to Biomedical Waste Management Guidelines for proper disposal of masks and other medical waste by all concerned is a must. Lockdown has brought about tremendous improvement in conditions of the world's atmosphere, hydrosphere, and biosphere. Dramatic improvement in air quality index, decrease in water, and noise pollution are some of the positive aspects of lockdown. However, these effects are temporary. But these teach an important lesson to the world to take some permanent measures to bring down greenhouse gases and other toxic emissions. Some harmful effects of lockdown are illegal deforestation, wildlife trafficking, encroachment of reserved areas etc.

Keywords: COVID-19; SARS-CoV-2; Environment; Zoonotic spillover; Bio-medical waste; Lockdown

Introduction

As the world was preparing to enter into a new decade (2020), a new virus emerged at Wuhan (China), crossing the species barrier affecting humans causing pneumonia like syndrome. In a matter of months, it reached every nooks and corner of the world due to the inter-country movement of people, rapidly resulting in an acute global health crisis. The World Health Organisation (WHO) named it the 'COVID-19' (coronavirus disease 2019) pandemic. 'CO' comes from the word corona, 'VI' is taken from virus and 'D' means disease. 19 denotes the year when it was first detected. It is caused by the novel coronavirus named 'SARS CoV-2' (severe acute respiratory syndrome coronavirus- 2) by the 'Coronaviridae Study Group (CSG) of the International Committee on Taxonomy of Viruses' based on phylogeny, taxonomy and established practices [1].

The most responsible reasons for this pandemic reaching such a huge magnitude include the large human population gathering, movement, and human interventions which have violated the ecosystem globally. Human beings intrude on the various untouched ecologies and put themselves before the unknown viruses and bacteria without knowing their threat or impact of exposure to humankind. Unprecedented containment, lockdown, and mitigation policies have been implemented across the world to limit the spread of the virus. Air travel restrictions, isolation, and quarantine, limitation of movement of people outside the home, closures of educational institutions, offices, business establishments, etc. are some of the measures undertaken to break the chain of transmission. This lockdown has led to unexpected consequences on the environment directly or indirectly [2],[3].

Thus, various facets of this ongoing pandemic are more or less intricately related to environmental issues. This review is aimed to highlight the impact of this disease on the global environment and the ecological factors responsible for the evolution of this deadly virus. It also throws light on how the various aspects of the environment are playing an active role in the disease dynamics.

2. The virus (SARS-CoV-2) and environment:

Wild animals and birds act as a vast reservoir of microorganisms, which are mostly non-pathogenic to human beings. Some of the deadliest diseases known are caused by emerging viruses (like Ebola, Lassa, Nipah, Hendra, orthomyxoviruses, etc.) that spread to humans from animal hosts are results of zoonotic spillover. The novel SARS-CoV-2 which comes under beta Coronaviruses is presumed to have come to humans from wild animals (bats and pangolins) due to the nutritional and cultural habits of the natives [4]. Wild life disease ecology has gained considerable attention as during the last century, 60% of all emerging infectious diseases have got zoonotic connection and 72% of them resulted from pathogens of wildlife origin [5].

The whole-genome sequence (WGS) of the novel virus genome reveals that it is 96.2% similar to that of a bat SARS-related coronavirus (SARSr-CoV; RaTG13) collected in Yunnan province, China. Comparatively, it has less similarity to that of human SARS-CoV (about 79%) or MERS-CoV (about 50%). It indicates that 2019-nCoV is closer to the SARS-like bat CoVs than the SARS-CoVs in terms of the WGS. Pangolins are hypothesized to have provided a partial spike gene to SARS-CoV-2. Spike proteins are the critical functional sites of the virus, which are nearly identical to those identified in pangolin coronavirus. Thus, the genome-wide phylogenetic tree of the initial isolates of SARS-CoV-2 indicates that SARS-CoV-2 was closest to RaTG13, followed by GD Pangolin SARSr-CoV, then by GX Pangolin SARSr-CoVs, then by ZC45 and ZXC21, then by human SARS-CoV, and finally by BM48-31 [6], [7], [8].

It is believed that the COVID-19 outbreak emerged from the Huanan seafood market, Wuhan, China. Later, after this outbreak, China had put a temporary ban on wildlife markets. Hence, we learn a valuable lesson that disturbing the natural biodiversity of a place can lead to the occurrence, emergence, and re-emergence of such infectious diseases with unprecedented magnitude and consequences. There should be adequate regulations and a ban on the consumption of exotic animals and birds like bush meat. A permanent ban should be applied to wild animal trading to ensure future safety.

Scientists have firmly ascertained that it is improbable that SARS-CoV-2 has emerged by laboratory manipulation of a related SARS-CoV-like coronavirus [9]. Although there is no credible evidence that SARS-CoV-2 is human-engineered, let this knowledge never take a backseat that viruses are the most potent weapon of bio-terrorism and can cause devastation of humankind. So, there should be conscientious preparation to prevent it by involving research and development on needed tools and approaches in the near future.

After the initial transmission of the virus from wild animals to humans, human to human transmission has occurred in the environment by inhalation of liquid droplets produced by patients, close contact with infected persons, and contact with surfaces contaminated with the virus. Recently transmission by aerosols has also been confirmed. A recent study in the New England Journal of Medicine found that viable virus could be detected in aerosols up to 3 hours post aerosolization [10]. SARS-CoV-2 is thought to survive for several hours on surfaces such as aluminum, glass, sterile sponges, or latex surgical gloves, increasing the opportunity for transmission via touch. Studies observed that it could stay viable up to 4 hours on copper, up to 24 hours on cardboard. SARS-CoV-2 can sustain on plastic for 72 hours with an infection capability of 103.7 to 100.6 TCID₅₀, whereas it can survive for 48 hours with infection capability of 103.7 to 100.6 TCID₅₀ in stainless steel [10], [11]. Therefore, alcohol-based or chlorine-based disinfectants can be used to reduce the load and survival of the virus on high touched metal or plastic surfaces. As per the information available at CDC, the risk of transmission of the virus that causes COVID-19 through sewerage systems is thought to be low.

3. The disease (COVID-19) and environment:

The pandemic, after its outbreak in China, rapidly spread to Middle-Eastern countries, Europe, and then to the American continent. Initially, the number of cases reported in India and other South-East Asian countries was low, but by the end of March, confirmed cases started to rise at an exponential rate. Very soon, it became a significant public health challenge for many countries. The health system and economy were crippled even in developed nations. [3]

An additional problem faced by many nations that adversely affected the environment during COVID -19 pandemic is the increased generation of medical waste. It is due to the high demand and use of personal protective equipment (PPE) and other disposable medical wares made of single-use plastics (SUPs). Their disposal demands large areas for the arrangement of incineration and landfill. It directly or indirectly gives rise to a wide range of environmental issues like air and water pollution, deforestation, soil erosion, etc. Wuhan hospitals produced about 240 metric tons of medical waste during the COVID-19 outbreak compared to their previous data that produced less than 50 tons[2],[3]. Similarly, in the USA, an increase in the use of PPE, masks, and gloves accelerated the generation of medical waste [2]. Reduce or ban in SUPs had been on top of political agenda across the world; but in this vigorous fight against the COVID-19 pandemic, many countries had to withdraw or postpone the ban on plastics. However, to reduce this plastic pollution, various recommendations and policies have been proposed[12]. Moreover, excessive use of disinfectants like sodium hypochlorite, chlorine, etc. in widespread sanitization drive may lead to water and soil pollution and can adversely affect people's health.

The most effective method to prevent COVID-19 transmission is the proper use of PPE/N95 masks in high-risk areas like hospitals, quarantine centers, etc., and use of ordinary masks, performing hand hygiene, and maintaining social distancing in other regions. But ignorance of its proper use and disposal is becoming a more significant health hazard than protection as people dump them on streets. Strict adherence to Biomedical-Waste (BMW) guidelines issued by the Central pollution control board and proper disposal is mandatory[13]. Instructions should be followed not just by isolation wards for COVID-19 suspects/patients of hospitals and diagnostic centers but by every quarantine centers or quarantine homes. Urban Local Bodies should take responsibility for ensuring safe collection and disposal of bio-medical waste, if any, generated from Quarantine Camps/ Quarantine Homes/ Home Care for COVID-19 suspected persons. Color-coded bins/double-layered bags designated for BMW should be made available wherever necessary. Even the general public should be made aware of proper use, handling, and disposal of protective masks through Information, Education, and Communication (I.E.C.).

Healthcare Facilities having isolation wards for COVID-19 patients need to follow these steps to ensure safe handling and disposal of biomedical waste generated during treatment; [13], [14]

1. Separate color-coded bins/bags/containers should be kept for maintaining proper segregation of waste as per BMW Rules, 2016, and should be labeled as "COVID-19 waste". (Figure 1 & Table 1)
2. Double layered bags (using two bags) should be used for collection of waste from COVID-19 isolation wards to ensure adequate strength and no-leaks.
3. Use of dedicated trolley and collection bins labeled as "COVID-19 Waste".
4. The (inner and outer) surface of containers/bins/trolleys used for storage of COVID-19 waste should be disinfected with 1% sodium hypochlorite solution daily.
5. Dedicated sanitation workers should be employed separately for biomedical waste and general solid waste (black/green bag). Waste collected in isolation wards should be lifted directly from the ward into the collection van.
6. Feces from COVID-19 confirmed patient, who is unable to use toilets and excreta is collected in diaper, must be treated as biomedical waste (yellow bag/container).
7. Proper disposal of PPEs such as goggles, face-shield, splash-proof apron, Plastic Coverall, Hazmet suit, nitrile gloves in Red bag and used masks (including triple-layer mask, N95 mask, etc.), head cover/cap, shoe-cover, disposable linen Gown, non-plastic or semi-plastic coverall in Yellow bags. (Figure 1)



Figure legend

Figure 1: Segregation of bio-medical waste generated in dedicated COVID hospitals and quarantine centers[13], [14]

Color of Waste bins/bags/containers	Categories (in broad terms)	Disposal
YELLOW	Infectious non-plastic, non-sharp, medicines	Incineration
RED	Infectious plastic, non-sharp	Autoclave or microwave
BLUE (box)	Sharp (metal)	Sharp pit
WHITE (thick box)	Glass, metal implants	Autoclave

Table 1: Biomedical waste categories and their segregation in different color-coded bins and disposal options[14]

The air quality seems to be a critical environmental factor in determining the severity of the pandemic[15]. A study conducted in Italy observed that people living in an area with high levels of pollutants are more prone to develop chronic respiratory conditions, and prolonged exposure to air pollution leads to a chronic inflammatory stimulus, even in young and healthy subjects.[16] Thus a high level of pollution in some cities, e.g., Delhi, should be considered an additional co-factor of the high level of lethality recorded in that area. Meanwhile, US researchers have found that air pollution particles may act as vehicles for viral transmission. As per the study by Xiao Wu and Rachel Nethery at Harvard University, an increase of just one microgram/M3 corresponded to an 8% increase in Covid-19 deaths[17].

Population density of a place is also playing a significant role in determining its disease burden as it increases the chance of transmission. It is already a known fact that overcrowding is associated with an increased risk of communicability in patients with certain infectious respiratory diseases like tuberculosis, influenza, and pneumonia. Household overcrowding leads to failure of containment strategy, and on the contrary, containment leads to further spread of the

disease as has been observed in Mumbai’s Dharavi slum (Asia’s biggest slum)[18]. With an increase in population, there is also a greater movement of the people. Interestingly, however, a US study found that higher population density is not linked with higher infection rates and, on the contrary, associated with lower COVID 19 mortality rates[19]. Table-1 shows the pollution level and population density of the States in India with the highest number of COVID-19 cases and casualties[20], [21], [22].

Ranking (by maximum death)	States	Confirmed cases	Deceased	Average Air Quality (AQI)Index of most affected cities	Population Density (persons/sq km)	Population Density of most affected cities (persons/sq km)
1	Maharashtra	468265	16476	129 (Mumbai)	365	31700 (Mumbai)
2	Tamil Nadu	273460	4461	125 (Chennai)	555	26,553 (Chennai)
3	Delhi	140232	4044	155 (North- East Delhi)	11297	36155 (North east Delhi District)
4	Karnataka	151449	2804	52 (Bangalore)	319	17000 (Bangalore)
5	Gujarat	66777	2552	152 (Ahmedabad)	302	9900(Ahmedabad)
6	Uttar Pradesh	104388	1857	165 (Ghaziabad)	828	3967 (Ghaziabad)
7	West Bengal	83800	1846	74 (Kolkata)	1029	24306 (Kolkata)
8	Andhra Pradesh	186461	1681	(not available)	308	NA
9	Telangana	70958	576	113	NA	18,172

Table 2: pollution level and population densities in the most affected states and cities of India

3. Impact of Lockdown on Environment:

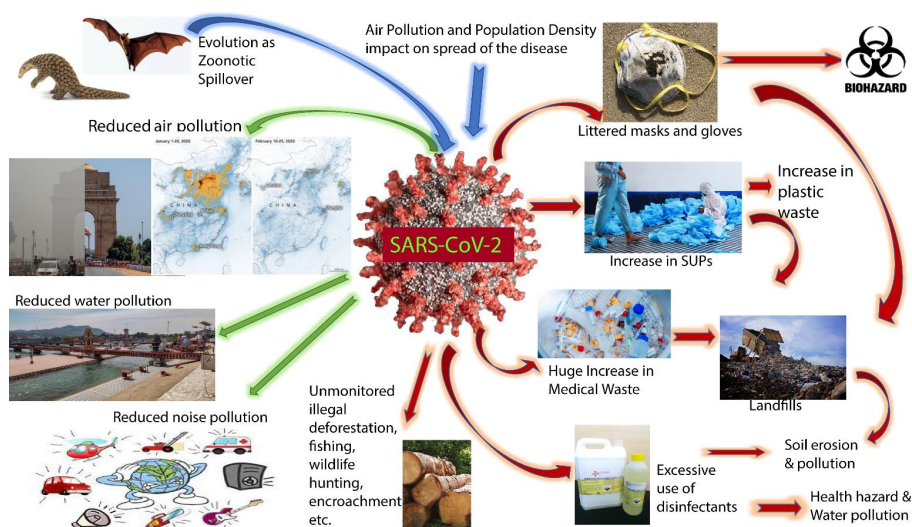
The silver lining in the thick of all gloom and doom is that mother earth is rejuvenated by restrictions imposed due to lockdown. Increased industrialization and anthropogenic activities have polluted the world's atmosphere, hydrosphere, and biosphere. The shutdown of factories and industries brought tremendous improvement to the air and water quality. Greenhouse gases started decreasing due to the limited use of air and road traffic. The Air Quality Index (AQI) has plummeted to unprecedented levels in major cities across the world [2]. The effect of COVID-19 pandemic on the environment monitored through the Tropospheric Monitoring Instrument (TROPOMI) on ESA's (European Space Agency's) Sentinel-5- satellite and Ozone Monitoring Instrument on NASA's (National Aeronautics and Space Administration's) Aura satellite, showed the decreased level of Nitrogen dioxide (NO₂) in the atmosphere. In India, air quality significantly improved in major cities like Delhi and Mumbai. Post-lockdown concentrations of PM₁₀, PM_{2.5}, NO₂ and SO₂ reduced by 55%, 49%, 60% and 19% respectively in Delhi whereas it is reduced by 44%, 32%, 78% and 39% respectively in Mumbai that indicated the positive impact of lockdown in these polluted cities [23]. Governments of most countries prohibited the free movement of the citizens in a bid to prevent community transmission. As a result, it had been observed that tourist spots like sea-beaches, mountains, became noticeably cleaner. The ozone layer had also started healing itself [3],[23],[24].

Lockdown restricts the working of many industrial plants that affects the aquatic ecosystem because of their industrial waste-water disposal, crude oil, and excessive plastics. As a result, a significant improvement could be observed in rivers, lakes, and other water bodies. In India, water quality evaluation in the longest freshwater lake Vembanad revealed considerable improvement in it. The analysis of suspended particulate matter (SPM) concentrations in Vembanad lake showed that the concentrations during the lockdown period were 15.9% lower than those in the pre-lockdown period on average [24]. Similar findings were observed in the Ganges, the sacred river of India, that became much cleaner than before lockdown [25]. With the entire humankind locked inside homes and decreased human activity, there was a significant reduction in noise pollution levels [26]. Seismic noise caused by human activity in Brussels, for instance, is reported to be down by 33% compared to pre-lockdown levels.

However, not all the consequences of lockdown on the environment are positive. Natural ecosystems and protected species are at risk during the lockdown as environmental protection workers at national parks, and land and marine conservation zones are required to stay at home, leaving these areas unmonitored. It has also led to the rise of illegal deforestation, fishing, wildlife hunting, illegal harvesting, and encroachment in many parts of the world [27]. The decline in ecotourism has compelled many people living in the vicinity of wildlife reserves to utilize resources from fragile ecosystems. Brazil and Colombia reported a steep increase in illegal logging and mining; the Philippines has also reported unlawful logging and wildlife trafficking. Kenya has recorded increased bushmeat and ivory poaching, as well as an increase in charcoal production, which has been illegal since 2018. Cambodia has seen a rise in poaching, illegal logging and mining, and similar reports have come from Venezuela, Madagascar, and South-east Asia [27].

Figure Legend

Figure 2: Impact of COVID-19 pandemic on and by the Environment



4. Conclusion

Environment and ecology provide all the necessary services to the fast-increasing human population and play a pivotal role in maintaining a balance in nature. Any human activity that tends to disrupt the balance can lead to unforeseen consequences. Keeping this in mind, global effort should be made to protect the environment from harmful human activities and maintain the equilibrium. Apart from posing a tremendous threat to public health, COVID-19 pandemic also has a colossal impact on nature. It is the duty of every man to be aware of the harmful effects of a massive load of waste generated in the fight against this disease and take all the necessary steps to prevent it. Lockdown and containments have brought about an immense improvement in atmospheric conditions, but it is temporary unless we take some drastic measures to cut down toxic chemicals and greenhouse gas emissions. It is a stark realization for human-kind that pollution is a global threat and can't be forgotten even in these challenging times.

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2. DK: Project administration, review & editing; Supervision;
3. DR: Resources; Software; Validation; Visualization

Conflict of Interest:

All the authors declare that there was no conflict of interest

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