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ASSESSING THE SYSTEMIC IMPACTS OF COVID-19 ON ENVIRONMENT, ECONOMY, AND PUBLIC HEALTH: A GLOBAL REVIEW TOWARD RESILIENCE AND SUSTAINABILITY

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ABSTRACT

Various environmental factors contribute to the onset and diffusion of pandemics, potentially leading to a gradual degradation of the environment. The emergence of the COVID-19 pandemic caused unparalleled disruptions globally, revealing vulnerabilities within the global community, notably among those who uphold democratic and liberal values. This situation has prompted new areas of research and discussions about the potential for a new world order, resonating with emerging perspectives. Subsequently, the COVID-19 epidemic has led to abundant environmental influences by the end of April 2020. The forthcoming new world order will likely possess greater internationalization compared to previous structures. Undoubtedly, it will significantly affect all facets of both national and international existence. Its effects, spanning from socio-economic dynamics to political and security concerns, vary considerably among different countries. There is a likelihood that developed nations might respond more effectively to this disease compared to underdeveloped countries. Potential and observed impacts on environment associated with COVID-19 were reviewed in this article. We contend that the impacts of pandemic are determined mostly by human activities obviously as anthropogenic factors reduces crossways the globe, and the effects on public health and cities will be sustained in the future.

Keywords: climate; COVID-19; global environment; individual and centre relationships; pandemic; SARS-CoV-2; sustainability

BACKGROUND

Different cases of pneumonia with unknown reason were reported at the end of 2019 in Wuhan, China (Lu *et al.,* 2020; Naseer *et al.,* 2023). In January 2020, SARS-CoV-2 (an acute respiratory syndrome) was discovered as a contributory agent through the deep sequencing analysis of samples collected from lower respiratory tract of infected patients (Huang *et al.,* 2020; Weaver *et al.,* 2022). On 13th January 2020, the initial inveterate case of pandemic was detected in Bangkok, Thailand (WHO, 2020). Director-General of WHO named this disease as COVID-19 on 11th February 2020. Moreover, 8565 confirmed cases and about 132 deaths were reported by the 2nd March 2020 in 67 different regions outside China. The disease has been professed as global epidemic on the March 11, 2020 (WHO, 2020; Chowdhury *et al.,* 2021; Mofijur *et al.,* 2021). The number of persistent cases has been steadily rising worldwide, with a sudden surge in reported instances occurring notably in low-income countries (Yin and Wunderink, 2018). We have reviewed the probable short- and long-term impacts of the epidemic on the emerging society, economy and the environment. In current review, the peak period of the pandemic and the consequent lockdown approach adopted to restraint the COVID spread was studied.

Symptoms Allied with COVID-19

The most common appearance of infection characterized with cough, chest imaging, fever, bilateral infiltrates and dyspnoea (Yang *et al.,* 2020). There are no precise medical features which can differentiate COVID-19 from alike viral respirational infections. Besides, rhinorrhoea, sore throat, headache, some gastrointestinal symptoms e.g.

diarrhoea and nausea were also reported in some patients (Lupia *et al.,* 2020). The main person to person transmitting route for the COVID spread is respirational droplet transmission by asymptomatic carriers (Lupia *et al.,* 2020; Yang *et al.,* 2020). The duration from the inception of this pandemic signs to decease arrays from 6 to 41 days with an average of 2 weeks (Wu *et al.,* 2019; Di Gennaro *et al.,* 2020), which is reliant on the immune system and age of the patients. The duration was shorter among the patients over 70-years as compared to those less than seventy years. The most reciprocated signs at beginning of COVID-19 ailment were croak, flue, exhaustion, fever, headache, sputum production, diarrhoea, haemoptysis, lymphopenia and dyspnoea (Di Gennaro *et al.,* 2020; WHO, 2020).

General Impacts imposed by COVID-19

Currently, in daily life, the impacts of COVID-19 are widespread and have far reaching consequences which are alienated together in Table 1.

Table 1. Sectoral Consequences of the COVID-19 Pandemic on Public Health, Social Dynamics, and Economic Activity.

Attributes	Consequences
Health Care	o Challenges in the analysis, isolation and treatment of suspected or inveterate cases o Over load on the working of the available medical arrangement o High protection prerequisite o Medical supply chain disturbances o High burden on medical pharmacies o Patients with other health complications are getting Abandoned o Over burden on clinicians and other healthcare specialists which are already working at a very high risk
Social	o Social distancing even with our blood relations and other close family members o Excessive stress among the people o Cultural, festive and all religious celebrations were banned o Closure of the restaurants, hotels, entertainment and religious places o Deferment of examinations or exemption from exams and promotion to the next grade with institutes internal assessment o National and international travelling was banned o Tournaments and other sports were cancelled or postponed o Proper services could not be provided by the service sector
Economics	o Essential goods manufacturing was slowed down o Disruption in the supply chain of goods o National and international business losses o Deprived cash flow in the market o Growth of revenue was significantly slowed down

The global economy and supply sources have been affected by this COVID-19 with limitations of global travelling. All governments, health bodies and other establishments are incessantly concentrating on recognising the cases pretentious by the COVID-19. Healthcare specialised face a lot of problems in sustaining the eminence of healthcare in these days (Huang *et al.,* 2020; Wang *et al.,* 2020).

Preventive Measures against COVID 19

The influence of COVID-19 can be reduced by preventive measures to achieve the required goals in the absence of effective treatment (Table 2).

Particularly, concerning the usage of face mask, medical care professionals were indorsed to wear specific gasmasks for instance FFP2 or N95, when carrying out aerosol-producing measures and to utilize medical masks while giving any medical protection to confirmed or suspected cases (WHO, 2020). Furthermore, all others with no respiratory signs were not obligatory to wear a medicinal mask in community, individuals suffering with breathing issues were suggested to wear medicinal masks both in home and health care surroundings (Hopman *et al.,* 2020).

Table 2. WHO and Global Health Authority Guidelines for COVID-19 Prevention and Personal Hygiene

COVID-19 prevention measures	WHO issued detailed guidelines
o Continuous use of face masks o Tissues should be used to cover sneezes and coughs o Hands should be washed on regular basis with soap or disinfect them with hand sanitizers which contained at best 60% alcohol o Avoid to interaction with infected persons o Maintenance of social distancing; and o avoid from touching mouth, nose and eyes with dirty hands o In case of indications, pursue medical care on priority basis o Follow assistance given by your healthcare provider (CDCP, 2020; Di Gennaro *et al.*, 2020).	o Thorough hands cleaning with sanitizers enriched with alcohol or washing them with water and soap on regular basis o Evade touching mouth, nose and eyes o Follow respiratory cleanliness by covering your nose and mouth with the help of your elbow or use the tissue during sneeze and cough o Rush to the medical care if found cough, breathing difficulty or fever o Stay conversant and follow instructions provided by your healthcare practitioner o Maintain social distance of about 3 feet (1 m) among yourself and someone who is sneezing and croaking (Di Gennaro *et al.*, 2020; WHO, 2020).

Environmental Impact of COVID-19: Disruptions and Emerging Opportunities

From the start of COVID-19, the impact of this epidemic on the environment gained attention, consisting of (a) observations as well as investigation of the instantaneous impacts and (b) approximations associated to long-run variations. Phenomenological expectations overcome, while constant quantifiable investigation must hold-up for appropriate data sets and further acquaintance. Mostly, ecological influence of the disease has not unswervingly caused from the concerned virus. The significance of sharply restraining or closing financial divisions, for instance hospitality businesses, transport or heavy industry has pretentious the environment directly. Furthermore, highly variable impacts the COVID-19 epidemic were observed on socio-ecological systems, from fundamental changes in individual routine, society as well as international matters (Nations, 2020) to basically enabling a quicker variation than would usually have developed (Haass, 2020). From the viewpoint of anthropocentric activities, the epidemic may direct to a more maintainable imminent scenarios, counting raised flexibility of the socio-ecological classifications or lessened supply chains that is a constructive progress. Though, it is still probable that a few states will regulate for reduced resilience by chasing quick economic evolution and concentrating less apprehension on the environment. The adverse impacts of the COVID-19 crisis are expected to have a substantial influence on society and the economy in general. However, they may also lead to some positive environmental changes. This issue involves the increasing amount of nonrecyclable trash and the generation of large volumes of kitchen waste because of the depletion of natural ecosystems (UNCTAD, 2020).

While the primary effects are alienated between fast environmental developments, for instance urban water and air quality, and pollution incidents, for example the ones instigated by the disposal of sanitary products, the predictable long- and short-run influences are mostly constructive.

Impacts are hardly restricted to improve the inventory and considerate, the effects of the pandemic on the substantial classification's emphases on the soil, water and air separately, with an accent on municipal zones. Megacities are often very unified erections providing a firm level of ease and safety for the inhabitant, but they intensify the acquaintance to particular intimidations. For instance, the densities with higher number of populations are more vulnerable to the threats. While in countryside, where the people tend to have grounds, the influence of the lockdown situations in metropolises exhibited more unadorned impacts on the cognitive health of people living in close accommodations. One of the important features of the epidemic incident in emphasis in current review is the spatial range but also changeability of the impact level. No other catastrophe has captured the globe with similar forces over so many municipal zones with multidimensional intimidations that are stimulating our metropolises throughout the catastrophe.

COVID-19 and Temporary Emission Reductions

The COVID-19 pandemic led to unprecedented reductions in human activity, profoundly impacting greenhouse gas (GHG) emissions and urban air quality. Le Quéré et al. (2021) report that global daily fossil CO_2 emissions declined by approximately 17% during April 2020 compared to 2019, with transport responsible for nearly 50% of the reduction, while aviation alone dropped by about 75%. Annually, global CO_2 emissions fell by 5.4% in 2020

from 36.7 Gt in 2019 to 34.8 Gt in 2020; the largest yearly decrease since World War II, although emissions rebounded nearly to pre-pandemic levels by late 2020.

Table 3. Temporal and Spatial Impacts of COVID-19 on the Environment: From Immediate to Long-Term Effects

Level	Days – Weeks	Months	Years
Local	○ Reduced level of noise pollution ○ Increased level of soil and water pollution due to the disposal of waste ○ Improved air quality in urban areas	○ Improved adaptation plans for urban areas ○ Improved air quality in urban areas	○ Improved adaptation plans for urban areas ○ Changes in social behaviour
Regional	○ Increased shoreline pollution with sanitary disposal ○ Less traffic, less environmental pollution	○ Improved environmental monitoring system ○ Policies for regional climate ○ Improved adaptation strategies	○ Improved environmental monitoring system ○ Enhanced regional climate ○ Improvement of inhabitants' wellness and health protection
Global	○ Reduction in the capacity of observational and monitoring data	○ Associated changes in economical and societal perspective with environmental impacts ○ Environmental research regarding epidemiological application	○ Policies against climate and environmental changes ○ Environmental research regarding epidemiological application
	Immediate	Short-Term	Long-Term

Satellite and ground-based studies in Pakistan's urban centres confirmed substantial air quality improvements. In Lahore, Khan et al. (2023) documented a 38% decrease in $PM_{2.5,}$ a 42% drop in aerosol optical depth (AOD) and 20–50% reductions in NO_2 and SO_2 during the March-May 2020 lockdown period compared to historical data (2015–2019). Similar reductions up to 30% in tropospheric NO_2 were observed across other South Asian cities via satellite analysis (Hassan et al., 2021). The temporary decline in emissions underscored the scale of anthropogenic impact but also revealed the fragility of these improvements. The IEA (2021) projected a rebound in power sector CO_2 emissions by 3.5% in 2021 as economies reopened and coal and gas usage increased. Friedlingstein et al. (2022) reinforced that while lockdowns delivered short-term gains (e.g., nearly 2 Gt CO_2 reduction), achieving sustained emission control demands structural transformations in energy and transportation systems.

Overall, COVID-19 delivered an unintended "natural experiment," showcasing that drastic emission reductions can yield rapid air quality benefits ($PM_{2.5}$ down by 38-60%, NO_2 by 2050%). Yet, these improvements were ephemeral GHG emissions and urban pollution rebounded highlighting the urgent need for strategic, policy-driven changes to transform such short-term reductions into long-lasting climate and health gains.

Impacts of COVID-19 on Water Resources and Aquatic Ecosystems

The pandemic introduced both direct and indirect influences on water and aquatic ecosystems most prominently through the emergence of wastewater surveillance but also via increased medical waste, shifting consumption patterns, and economic strain on water infrastructure. Early studies confirmed the detection of SARS-CoV-2 RNA in municipal sewage, leading to the development of wastewater-based epidemiology (WBE). Medema et al. (2020) demonstrated how routine sewer sampling could serve as an early indicator of community infection levels even preceding clinical diagnoses. The presence of viral RNA does not imply active infectivity; standard water treatment

processes effectively deactivate viruses, particularly at elevated temperatures (Gundy et al., 2009). A surge in PPE usage led to a rapid increase in single-use plastics and medical waste. By mid-2020, reports from coastal areas in Canada and Hong Kong highlighted PPE items washing ashore, posing ecosystem risks and entanglement hazards for marine wildlife. Hospital wastewater analyses (e.g., Bucharest, Romania) revealed heightened antibiotic and biocide loads, which coincided with increased antibiotic-resistant bacteria. Although overall microbial concentrations dropped during lockdown, resistant strains persisted post-pandemic. Immediate lockdowns led to reductions in industrial and agricultural water usage, but these were temporary and closely tied to economic downturns. Recovery of industrial activity reversed this trend by mid-2021 (Ibrahim, 2022). Tourism-dependent regions experienced measurable declines in freshwater abstraction during 2020, while domestic water demand rose-prompting stresses on municipal systems and uneven service delivery (Staddon et al., 2020).

Pandemic-Induced Risks to Soil Ecosystems and Sustainable Land Use

Soil delivers vital ecosystem amenities for human socialization, fluctuating from agriculture to carbon confiscation that are essential for numerous Sustainable Expansion Goals (SEGs), for instance "Life on Land" or "Zero Hunger" (UNO, 2020). The instant effect of the epidemic or other analogous catastrophes on the soil environment is accompanying with the growing dangers of food uncertainty and disturbance in the food chain supply.

The perseverance of SARS-CoV-2 on diverse surfaces is a main problem for effective control of its blowout. These viruses can persist actively on surfaces for numerous days (Van Doremalen *et al.,* 2020). Another study explored the existence of numerous viruses in sediments and soils (Nag *et al.,* 2020). Currently, there is no vibrant sign against the part of the environment of soil in transference or accommodating of the SARS-CoV-2 nor regarding the influence of this virus on soil surface, and demands for assembling subsequent consequences have been dispensed (Nunez-Delgado, 2020).

COVID-19 and Nature's Vulnerability

From the viewpoint of ecology, the crises of COVID-19 are essentially associated to the contacts between ecosphere and society. Tough the source in industrial livestock is not up till now completely clarified (Andersen *et al.,* 2020), SARS-CoV, MERS-CoV and SARS-CoV-2 are known as animal coronaviruses that infested individuals and flourished to blowout in diverse societies at high level. Globally, about >2.7 million persons are vanishing from zoonosis within a year (Grace *et al.,* 2012) but the effect is even larger when considering the deterioration of agriculture, human wellbeing and livestock sector, while, poorer community are more vulnerable in general. The crises of pandemic are most possibly among the various encounters our community will have to encounter in the imminent years as an incidental significance of the effect of climatic variation on the biosphere over several structures, counting lessening genus environments (Corlett *et al.,* 2020), altering genus disseminations (Zhang *et al.,* 2019) and a growing invasion of alien hostile species (Dukes and Mooney, 1999). Presently, economic expansion emphases on incessant development without seeing the preservation of natural systems. Division of forest landscape may enable more often human interaction with wild creatures, growing the probability of spread danger of animal-to-human viruses (Bloomfield *et al.,* 2020; World Economic Forum, 2020).

The epidemic also affected environmental investigation, field-work and experimentations. In various instances, this investigation ventures were halted or diminished, with significant significances on preservation of habitats and species. Moreover, there is also a probable economic influence on preservation plans globally as an outcome of epidemic and diverse programs are evaluating their long-run feasibility (for example fund for the Global Environmental) (Corlett *et al.,* 2020). After the end of this pandemic, a risk occurs that both conservation and research programs will be reduced mostly because of the miscommunication between scientists and decision makers. Though, possibly the most significant impact of the epidemic on the environmental evolution emphases on resilience and the still probable adoptions that the humanity could make to guarantee its long-run subsistence.

The uncertainty induced by the epidemic is categorised by covariant that have abrupt and manifold influences on both the society and on inherent environment and could impulse the set-up into three diverse possible circumstances. The quick multivariate are illustrating the variability stage and the deliberate variants act as regulatory variants (Holling, 1985; Carpenter and Turner 2000; Crepin, 2007). The main distinctive outcome of the epidemic is that it is working as a shock wave that impulses the set-up to a dominion shift with hard to forecast significances. Nature is fragment of the infusion for retrieval and maintainable reform. Yet, the consequence of the epidemic on environmental structure has not yet been completely comprehended, and additional surveillance will fetch new discoveries and perceptions (World Economic Forum, 2020).

COVID-19 and the Reshaping of Global Environmental Diplomacy

On international level, the reshaping of environmental and economic policies due to the COVID-19 pandemic is expected. The strength of few international partnership and bilateral agreements has been experienced by this epidemic. While China insistently capitalized in Africa's intrinsic resources as well as substructure ventures, the dealing of African inhabitants residing in China and the hindrance at Beijing's antagonism on permitting liability ease could depreciate the Chinese political and economic sovereignty in African countries (Coronavirus China Africa, 2020). The effect of the catastrophe on African financial prudence with volatile environmental costs is also conferred in a study (Ataguba, 2020). USA and China are playing a significant role to mitigate danger include an environmental prominence to the epidemic policy readiness with the intention to shield the global public from zoonotic sickness (Evans *et al.,* 2020). The widespread coronavirus could substantially influence the European and Italian relationship, as specified by the extensively spread insight that the Europe was not competent enough to fight against Coronavirus (Italy, Coronavirus and EU, 2020). Such variations are projected to produce incidental long-span environmental effects. Climatic variations are often supposed as a hazard causing globally and pandemic has presented a brilliant illustration of how a solo undervalued risk can provoked the fundamentals of democratic governance, universal certainty and economic strength (Guy, 2020).

Local commitments were also threatened by the risk of Coronavirus to implement adaptation as well as mitigation measures against climate change that have been originated in the current era (Avenue, 2020). All the governments will be equally affected worldwide, whereas longer-time impacts are also projected, most of them straight away linked to urban zones and public safety. It is recommended that the perception and application of the plan must be re-evaluated conferring to the advanced discoveries interrelated with our acquaintance, liabilities and strength to the global catastrophic hazards. The crises of pandemic have confronted environmental surveillance and climate amenities, generating both difficulties in monitoring and challenges to produce improved preparation.

Interlinked Dynamics and Implications of Climate Change and COVID-19

Disease transference due to the mobility of people within the framework of climate change becomes the issue of attention for scientists even before the existing epidemic (Cooney, 2011; Amon, 2016). The investigation of the association between Coronavirus and climate emphases on two interrogations: (i) in what way the climate can moderate the growth as well as viral endurance, and (ii) the level of the influence of the virus on economic strategies taken to counterbalance climate effects. The first feature is intrinsically empirical and mostly includes the disciplines of epidemiology and atmosphere. More complexity was observed in 2^{nd} query as the social, economic and political dynamics will disturb procedures which may change our worldview. It is difficult to estimate the effects of climate on the Coronavirus because of the prolonged prevailing condition of this pandemic. These possessions, consequently, can only be ventured by equating them to the physiognomies of alike coronaviruses. The detected expansion frequency of Coronavirus globally and its linkage to the climate was inspected in a study (Araujo and Naimi, 2020) which assemble an estimate for imminent spells. They contend that the optimal spread of coronavirus occurs at a specific climate. Epidemic dynamics were also inspected in terms of environmental and climatic conditions (Ficetola and Rubolini, 2021) to associate daily growth level to the regional climate directly. Significant association was found directing them to accomplish that such a correlation was rational, but the fact that density of population could be a mystifying variable was also highlighted in their study. These results, even though very hypothetical, directed to preliminary theories on the spread circumstances of SARS-CoV-2 under diverse amalgamations of meteorological constraints (Wang *et al.,* 2020) and to estimate circumstances for the summer season of 2020 (Bukhari and Jameel, 2020; Carleton and Men, 2020). An equivalence with the similar Coronaviruses develops basics to authenticate such theories but it is not presently probable to create whether the virologist features of the novel virus can be supposed to be alike other coronaviruses.

Indirect and direct impacts of epidemic on the climate are difficult to analyse as predictions must rectify not just the infection flux but also integrate political, economic and social characteristics of the virus proliferation. Globally, the slowdown of transportation and production activities could be attributed as direct effects on climate change. At this phase, discharges in China—the state with the lengthiest closure period—have reduced by 25% approximately (Economic Slowdown WMO, 2020), consistent to a reduction of around 200 million tons of CO_2 in February solely (Carbon Brief Report, 2020). However, about 5% of probable CO_2 emission reduction is expected globally (Carbon fall by Coronavirus, 2020). Specialists propose one of two abruptly deviating tracks will arise from the decease of the epidemic (Climate after Coronavirus, 2020). Contrarily, a feeling occurs that the Pandemic will sustenance the business infrastructure, government and science in addressing environmental problems, counting climate change (Allen *et al.,* 2020).

Even though the climate change and Coronavirus work on diverse time spans, they signify alike incident in the course of the development and influences of the issue. Retrieval from the epidemic, consequently, may direct to the

emphasis away from environmental apprehensions (Tollefson, 2020). Assuredly, somewhat has previously altered. This pandemic has destabilised the basic creeds of world-wide manufacturing. Businesses must now reassess the transition state, supply chains of multi-country that influence production level (Carbon fall by Coronavirus, 2020). People must reassess life adoptions as reflective variations also await us (Carbon Brief Analysis, 2020; Cheval *et al.*, 2020; Maynard, 2020).

From Vulnerability to Preparedness: Strategic Shifts Post-COVID-19

The COVID 19 pandemic has revealed deep vulnerabilities in both developed and developing nations. In high-income countries such as the USA and Italy, the pandemic's impacts on health, economy, and social systems were profound, yet resource buffers such as fiscal stimulus and healthcare infrastructure mitigated worst-case outcomes. In contrast, developing countries faced acute shocks with limited capacity to respond; lockdowns disrupted informal and formal sectors, causing unemployment to spike. Past restrictions relied heavily on case tracing, quarantines, and decentralized lockdowns necessary but unsustainable long-term solutions. A strategic pivot is needed toward digital infrastructure and resilience-building. Online education, though initially emergent out of necessity, shows promise as a scalable tool: medical education in Pakistan achieved equivalent or better outcomes through structured remote learning and active pedagogies. Systematic reviews continue to report positive student engagement and performance outcomes in hybrid and online modalities when thoughtfully designed. Digital platforms thus offer a route to preserve education continuity, widen access, and enhance resilience during future disruptions. However, long-term, equitable adoption depends on investment in broadband, teacher training, and inclusive content design. Overall, while COVID-19 forced reactive strategies, the path forward lies in proactive resilience: enhancing digital human capital, safeguarding informal livelihoods and reforming healthcare and education systems to withstand future shocks.

Conclusions

The COVID-19 pandemic has significantly disrupted environmental, economic, public health and social systems at multiple scales. While temporary ecological benefits emerged due to reduced human activity, these were offset by long-term economic losses, health risks and increased environmental pressures such as medical waste. The crisis underscores the interlinkage between planetary and human health, emphasizing the need for integrative, adaptive and resilient policy frameworks. As the full extent of the pandemic's impacts continues to unfold, it offers critical lessons for building preparedness against future global health and environmental emergencies.

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