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Indirect implications of COVID-19 towards sustainable environment: An investigation in Indian context

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A B S T R A C T

Efficacious transmittal of COVID-19 has compelled numerous countries worldwide to embrace temporary yet dramatic measures such as locking down entire cities, restricting all forms of transportation, imposing lockdowns, maintaining social distancing etc. These actions have considerably enhanced the quality of ambient air and water. India, being a densely populated country, imposed a strict nationwide lockdown mandate since the last week of March 2020. This paper discusses the effects of COVID-19 restrictions on several aspects of environment broadly in Indian scenario. The forward course of action in the present and probable scenarios has also been addressed. As the disease spread is still underway, lockdown restrictions yet to be lifted and the availability of metadata hitherto being restrictive, firm deductions and explications could not be made. This case study i.e. observing the effects of lockdown, is a unique opportunity to understand how the environment reacts to sharp reductions in anthropogenic activity.

1. Introduction

Towards the end of 2019, started in Wuhan, the capital of Hubei province in China, with an exceptionally high number of pneumonia cases of unusual characteristics is a novel infectious coronavirus disease. The causative agent of the outbreak was identified as beta-coronavirus with a genomic sequence closely related to that of the severe acute respiratory syndrome (SARS) coronavirus from 2003, earning the new virus the name SARS-CoV-2 (Zhu et al., 2020). This 2019-disease, also named as COVID-19, has quickly transformed from a regional outbreak in China into a complex global pandemic, resulting in almost 10 million cases worldwide cases within the first five months. The large-scale outbreak has spread to more than 216 countries, regions and territories across the world, yielding more than 9,527,123 infected cases and 484,972 deaths globally as of 25th June 2020 (WHO, 2020b).

Several nation states including the United States, Germany, France, Spain, Japan, Singapore, South Korea, Iran, and Italy have reported community transmission (Amanat and Krammer, 2020); with the United States experiencing the highest impact and number of deaths of any individual country (2,462,554 confirmed cases and 124,281 total deaths as of 25 June 2020 16:00 ET) (CDC, 2020). The total reported cases and deaths in India have been highest in the Asian continent and have reached 472,985 and 14,907, respectively as of 25 June 2020 16:00 ET (MoHFW, 2020).

As there is no vaccine/antibody officially available till date, the governments and local authorities in numerous countries have imposed/proposed lockdowns to restrict the movement of people and maintain physical distancing. As a preemptive preparedness and prophylactic measure, the Government of India (GoI) initiated a 14-hour citizen-led voluntary social distancing campaign (Janata Curfew), on 22-March-2020 (07:00 AM-09:00 PM IST) excluding essential services (such as medical services, police forces). Further, as the disease spread was assessed to be hitherto imminent, the Indian government announced a mandatory lockdown with no trans-boundary movement (internal (interstate and intrastate) and external) and strict social isolation measures. The nationwide mandate, applicable for the entire 1.35 billion population, came into effect on 25-March-2020. Thenceforth until 18-May-2020, the lockdown in India has been renewed four times: Phase-I (L1) ending on 14-April-2020 (21 days); Phase-II (L2) ending on 03-May-2020; Phase-III (L3) ending on 17-May-2020; Phase-IV (L4) ending on 31-May-2020 (14 days); Phase-V (L5), only for containment zones, ending on 30-June-2020 (30 days). Different phases of lockdown have different forms/levels of restrictions in different locations/zones. The first phase observed an adjournment of almost all forms of transportation, construction, services and industries except media, medical services, fire-fighting and police forces, and vendors/e-commerce suppliers. Before reinstating the lockdown to Phase-II, GoI classified lockdown areas into three different colored
zones: Red (infection hotspots); Orange (some cases) and Green (zero cases). Conditional relaxation was allowed depending upon the extent of outbreak. Restricted social, industrial, commercial activities certainly impacted surface water quality, air pollution levels, GHG emissions, noise levels, waste generation rates and its composition. Analysis of these pivot sections of the ecosystem could assist and reduce prospective challenges of ongoing environment preservation schemes in India. Conditional relaxation was allowed depending upon the extent of outbreak. Restricted social, industrial, commercial activities certainly impacted surface water quality, air pollution levels, GHG emissions, noise levels, waste generation rates and its composition. Analysis of these pivot sections of the ecosystem could assist and reduce prospective challenges of ongoing environment preservation schemes in India.

The biggest question related to the environmental impact of the crisis is that ‘could the crisis following the 2019-coronavirus outbreak actually be good for the environment?’

As in many parts of the world where people have been living in lockdown, traffic has nearly stopped and nitrogen dioxide emissions have dropped, satellite images and ground data seem to prove that (NASA, 2020). Although global anthropogenic/economic activities have been put into, hitherto, an induced coma (NASA, 2020). Also, premature mortalities caused by PM2.5 emissions in India were reduced by ~5300 after two weeks of announcement of lockdown (Venter et al., 2020).

Janata Curfew (on 22 March 2020) had shown that most of PM2.5 in Mumbai is reliant on transport and industrial contributions. Moreover, sudden increase in CO levels was observed after announcement of lockdown L2 with conditional vehicular movements which ultimately got reduced minimally after April 25, 2020. Similar reasons could be attributed to sudden increase in PM10, O3 and SO2 during initial phase of lockdown L2 in cases of Delhi and Chennai. Particulate contribution from the industrial sector and transportation sector has seen the sharpest decline, followed by NOx emissions from road-based vehicular transport. Unlike in China or the USA, phase-I restrictions of lockdown (L1) in India were implemented consistently across the nation. This spatial uniformity in reduction of anthropogenic emissions is expected to decrease the pollutant contributions from/to long distance transport, Guo et al. (2017), who conducted source apportionment studies of PM2.5 in North India, concluded that a particular fraction of primary particulate matter (PMM) is contributed upon by emissions from Pakistan. Trans-boundary anthropocentric PM entering India was presumed to decrease, as the neighboring countries also had enforced restrictions to varying extents. Aerosol concentrations were at the lowest of past 20-year during lockdown L1 in northern India (NASA, 2020). Further, substantial precipitation over sizable areas of Northern India (on March 27, 2020; just after imposition of L1), could have also assisted in clearing the aerosols. The aerosol optical depth (AOD) levels observed over the entire Northern India were between 0.1 and 0.2, confirming clear sky and maximum visibility. An anomaly in AOD, presented by NASA (2020), has exposed with Indo-Gangetic Plain (IGP) undergoing steepest decline (Fig. S2). However, AOD over southern India doesn’t share a similar trend; in fact, AOD in certain regions is slightly higher than in the past years.

Reduction in air quality index (AQI) of various cities in India was observed during lockdown period. More specifically, nearly 30% decrement in AQI was recorded while comparing the previous years’ values (Sharma et al., 2020). North India observed a highest reduction of ~44% followed by southern and western India (~33% and ~32%, respectively) (Fig. S1). The cities of East India have shown the sharpest decrease in PM2.5 values followed by North Indian cities (Sharma et al., 2020). Moreover, dominant pollutant for various cities changed from PM2.5 to O3 in Kolkata, Gaya, Nagpur and Kanpur; while NO2 in Agra and Patna (CPCB, 2020a). Other positive aspects of positives caused by lockdown are: reduction in pollutant absorbance, increase in optical density and greater visibility. After 10 days of implementation of lockdown (on 03 April 2020; during L1 phase), favorable meteorological conditions and reduced AQI in Jalandhar, Punjab—facilitated
its residents with a view of Dhauladhar mountain range (Located > 200 km from Jalandhar in Himachal Pradesh) of the Himalayas (Fig. S3a and S3b) (Trisha Sengupta, 2020). On a similar note, after nearly a month into the lockdown (post-L1; during L2 phase), the AQI of Saharanpur, Uttar Pradesh dipped below 50 — allowing its citizens to view the Himalayan peaks and ranges which are located around 160 km away (Fig. S3a and S3c), especially the inner Himalayan peaks of Bandarpunch (Sankari range) and Gangotri. The residents, in both the incidents, beheld the Himalayas after > 30 years.

2.1.2. Effects on Indoor air quality

The indoor air pollution status during COVID-19 is counterintuitive of overall reduction in ambient air pollution. With lockdown in place, the population in all sections of society (urban and rural) are living/spending maximum clock hours inside houses, which results in generation of more indoor pollutants and prolonged exposure to those increased indoor emissions. The rural areas add smoke (rich in black-and organic- carbon), from cooking and prescribed farming fires (be that as it may, much of crop burning on farms occurs during other times of the year) (NASA, 2020). Majority of households in India cook using direct combustion of fuel, which produces more pollutants than electric cooking. Bulk of rural India and urban slums have minimal access to clean cooking systems and rely on firewood, charcoal or kerosene. These emissions and prolonged exposure during lockdown combined with other day-to-day activities performed indoors (like smoking, use of industrial cleaning products, burning incense, contact near paints and wood preservatives etc.) exacerbate the impact of indoor air quality on its residents, compared to normal conditions. Improved ventilation can reduce the aforementioned impacts, as reported by Bhatia and Bhaskar (2020), but indoor air conditioning/mechanical ventilation can lead to increased spread of COVID-19 infection.

Fig. 1. Variations in pollutant concentrations across different phases of lockdown (L1, L2 and L3) in 4 megacities of India.
2.2. Impact on surface water quality

The stringent lockdown measures have had a marked effect on India's rivers and other lotic ecosystems. The water quality achieved by Ganga, India's longest and holiest river, within a few weeks of lockdown was more pronounced than what governmental policies/regulatory agencies accomplished in decades. Of the 36 real-time water monitoring units located along Ganga, 27 have shown a water quality suitable for ‘bathing’ and ‘propagation of wildlife and fisheries’ (Singhal and Matto, 2020). The upper reaches of Ganges have seen the sharpest improvement. Tests conducted by Uttarakhand Pollution Control Board (UKPCB) on water samples from Har-ki-Pauri in Haridwar revealed that the river water had become ‘fit for drinking’ for the first time after more than three decades (Katariya, 2020). This improvement in water quality at Haridwar and Rishikesh was attributed to drop in the number of visitors at Ghats, and 500% decrease in sewage and industrial effluents (Singhal and Matto, 2020). The water quality had improved to dramatic levels just after 3 days in to the lockdown (Table S2). In another study by CPCB (2020b), a comparative assessment of water quality of river Ganga during pre- and post-lockdown (L1) was carried out, after gathering data from 8 real time water quality monitoring systems (4 stations in each of the states, Uttar Pradesh (UP) and West Bengal (WB); refer Table S3). The variations in the physicochemical properties of Ganga River water, before and after 1, 2, and 4 weeks of lockdown (L1) enforcement (i.e. 1WL, 2WL and 4WL, respectively), are presented in Fig. 2. During 2nd week of lockdown (2WL), the increased level of dissolved oxygen (DO) was observed in all the stations over the stretch of river Ganga, except nuanced decrease in UP 04, WB03 and WB04 stations which experienced heavy rains during this period (IMD, 2020). This decrement in DO levels is attributed to increase in suspended organic loading and turbidity that proceeded after an intense precipitation in the eastern UP (UP04) and western WB (WB03 and WB04) region. During 4WL, decrease in the level of DO as compared to pre-lockdown (PL) was recorded at every station of UP unlike DO values in WB stretch. It can be noted that the biochemical oxygen demand (BOD) and chemical oxygen demand (COD) has decreased significantly over the period of a month in to lockdown; however, within one week, a steep increase in COD was recorded at UP03 and WB02. Discharge of polluted water through the tributary Pandu River and confluence of industrial effluent generated by rice and oil seed mills into the mainstream could be the probable respective reasons for sudden increase in observed COD. Also, at most of the sampling locations, COD values are not in consonance with BOD variation, showing continuous wastewater discharge in the tributaries and mainstream. Restricted industrial and agricultural activities amid lockdown caused decrease in nitrate levels, which were recorded in the range of 0.5–2 mg/L (attaining a decrement of 2 to 66% among all the selected stations). Additionally, concentration of ammonical nitrogen (NH4+-N) increased among all the stations (ranged between 0.15 and 1.75 mg/L over the whole stretch of river) due to continuous release of raw or partially treated sewage into the river. Although NH4+-N levels increased slightly, its overall measured concentration was below set standard for ammonia.

Surface water qualities of river Yamuna (at locations Palla, Nizamuddin Bridge and Okhla upstream), the largest tributary to river Ganga, and two of its major drains (Najafgarh and Shahdara) from Delhi are presented for pre- and post-lockdown (L1) period in Fig. 3. CPCB (2020c) reports a considerable decrease of ~51.46%, ~74.69% and ~78.57% for DO, BOD and COD, respectively of rivers at Palla station. In fact, BOD (2 mg/L) at this station was below drinking water permissible limit of 3 mg/L (Fig. 3(c)). DO at Nizamuddin Bridge and Okhla increased from 0 to 2.4 and 1.2 mg/L, respectively (Fig. 3(b)). Continuous freshwater flow into the river from the Wazirabad barrage and Hathkund barrage, minimized human activity (bathing, cloth washing, disposal of solid waste and religious material etc), and restriction of industrial wastewater confluence in to the mainstream could be the causes for the above variation. Samples from Palla showed a higher change of pH (~0.9) compared to other sampling locations (Fig. 3(a)). Katariya (2020) reported increase in secchi disk depth (a measure of water transparency) of river Yamuna to the levels last seen 42 years ago. Kapil (2020) mentioned that, in Delhi, domestic sewage comprises 80% of pollution load and this proportion has increased during lockdown. According to national water quality standards (CPCBNVIS, 2020) (http://cpcbnvis.nic.in/waterpollution/criteria.htm), river water can be denoted ‘fit for bathing’ status if its total coliform count is < 500 mpn/100 mL. The faecal coliform count at Nizamuddin and Okhla Bridge, in 2016, is as high as 9,200,000 mpn/100 mL; and as the pollution load from domestic sewerage has not dropped even after lockdown, the coliform count in areas like Palla and Nizamuddin Bridge have not come down (Kapil, 2020).

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**Fig. 2.** Water quality characteristics of middle (Uttar Pradesh stretch) and lower (West Bengal stretch) reaches of river Ganga.
Several other rivers across India have seen similar improvements in their water quality. After decades of being dark and frothy (due to convergence of untreated domestic sewage), the water of Vrishabhavathi River, of Bengaluru, turned clear (Katariya, 2020) and convergence of untreated domestic sewage), the water of their water quality. After decades of being dark and frothy (due to increased sightings of Indus river dolphins, one of the world's rarest mammals) (TOI, 2020a). Due to closure of Textile and Tannery processing industries, effluent discharges into the waters that lead to Kalingarayan canal of Erode, Tamil Nadu have completely stopped, similarly, the flow in Buckingham canal recorded minimal sewage contamination. Keeping in view of above-presented data, it could easily be inferred that implementation of lockdown to prevent COVID-19 transmission, indirectly benefitted the self-cleansing of Indian rivers.

2.3. Impact on waste generation and handling

So far there is no proven case of COVID-19 transferred through healthcare waste. However, excessive volume of COVID-19 waste (personal protective equipment (PPE) kits, surgical mask, gloves) has become a significant challenge for its proper handling to the waste management authorities. According to occupational safety and health administration (OSHA, 2020), waste workers are at higher risks of exposure to the virus.

Recently central pollution control board, India (CPCB), world health organization (WHO), centers for disease control and prevention (CDC), international solid waste association (ISWA), occupational safety and health administration (OSHA) and many other organizations have come up with the guidelines to handle biomedical waste during this pandemic. The main focus of all the guidelines is on the excessive protection and safety of waste workers while collecting COVID-19 waste. WHO and CDC have classified COVID-19 waste into two categories:

a. *Inside hospitals and health care facilities waste:* All the waste generated inside the treatment facilities should be considered as medical waste and shall be collected and handled with extra precautions and care.

b. *Outside healthcare facilities waste:* It includes the waste generated as a result of social distancing and preventive measures i.e. masks, gloves. As per WHO and CDC, this waste should be treated as the non-hazardous waste and can be sent to the sanitary landfills.

The waste industry in India even pre-COVID-19 pandemic had limited capacity and service provision, which now is being hit the hardest in the following ways: 1) Waste collectors are now handling potential infected waste, and 2) Lack of safety and personal protection gears increasing their exposure to COVID-19 virus. This section presents the latest information on the change in the generation, collection and handling of waste during this unprecedented time. The information presented in this section is collected from the central and state pollution control board(s), local government authorities and landfill operators. The major changes noted in the waste management sector during the lockdown are: a) increase in the amount of infectious/biomedical waste (BMW), and b) decrease in the amount of municipal solid waste (MSW) reaching landfills/dumpsites. Some of the important observations are listed below:

2.3.1. Handling of biomedical waste

Around 500 metric tons/day (MT/day) of BMW was generated in India in 2017 (Datta et al., 2018). However, till date, there are no official records available about the alteration in the generation of BMW during this lockdown period. Coronavirus epicenter Wuhan witnessed a six times increase in BMW during the peak of its outbreak (SCMP, 2020). Based on the telephonic conversation with medical staff, it was changed to levels that are within the set standards, turbidity has shown no improvement (Turbidity: Cauvery- 190 NTU, Krishna- 700 NTU, Prescribed limit- 1-5 NTU) (Thakur, 2020). Post-lockdown (L1), the floating trash barrier placed on Cooum River near Napier Bridge in Chennai is nearly empty, but the domestic sewage continues to flow into Cooum and Adyar rivers (Tannery effluents into Adyar River is completely halted). Significant recoveries in water quality have been observed in Kallayi River of Kozhikode, Kerela (DNA, 2020) and Beas River in Punjab (resulting in increased sightings of Indus river dolphins, one of the world’s rarest mammals) (TOI, 2020a).
found that the generation of BMW has increased by 40 times in the last 2 months in one of the highly affected metro cities (Gurugram) of India. In the city of Ahmedabad, the biomedical waste that used to be 550–600 kg/day in the normal has increased to 1000 kg/day during the first phase of lockdown. It was anticipated that the generation of BMW waste can further go up to 3000 kg/day as the rampant use of masks and waste coming in from quarantined areas (TOI, 2020b). At present, waste can further go up to 3000 kg/day as the rampant use of masks.

In the city of Ahmedabad, where the generation of construction and demolition waste used to be 1000 MT/day during normal days, has now reduced down to nearly zero, as almost all the construction activities are temporarily stopped. Commercial unit waste collection that used to range from 650 to 700 MT/day has also stopped now (TOI, 2020b).

2.3.2. Change in the generation of MSW

The implication of quarantine measures by the authorities has caused people to stay home. The changes that arose after the announcement of lockdown have caused the waste generation to drop significantly. The nation has seen a major change in the amount of waste reaching the landfills/dumpsites in the last two months. This may be due to the closure of all the restaurants, markets, malls etc. during the lockdown period. A remarkable reduction in the quantity of dry waste was observed due to closure of shops, malls, offices etc. One of the possible reasons for decreased waste quantities could also be the poor collection efficiency, as the number of employees involved in the waste management sector has reduced. After the imposition of the lockdown, many waste-pickers could not pick up waste either because of restrictions by police or apartment societies, affecting waste collection. Fig. 4 shows the amount of waste reaching the landfills/dumpsites before and during lockdown (L1) in ten landfills of India. It can be seen that around 20–40% reduction is observed in the quantity of waste at most of the landfills/dumpsites after the lockdown. A drastic reduction (> 80%) in the generation of waste at Rajkot was noticed. It may be due to the migration of the workers to their home states from the industry-dominated city.

The quantity of waste reaching dumpsites of Delhi ranged between 3000 and 3700 MT/day in normal days (before lockdown) while during the lockdown period it reduced down to 1800–2500 MT/day. The waste quantities reaching at landfills located in Hyderabad, Pune, and Panchkula were 5800–6000, 2100–2200, and 150–160 MT/day respectively before the lockdown, however, it reduced down to 4700–4900, 1400–1500, and 100–100 MT/day respectively during the lockdown. The total waste being generated by the four cities of Gujarat (Ahmedabad, Vadodara, Surat and Rajkot) has reduced down approximately by 20–80% during the lockdown period (Fig. 4).

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2.3.3. Reduction in waste recycling

Waste resource recovery from collection trucks and landfill has always been a major source of manufacturing inputs for the recycling industry. As a result of the pandemic lockdown, recycling activities are stopped because local authorities, formal, and informal sectors are concerned about the risk of contaminated materials spreading among the waste handlers. Due to the massive lockdown, around 46% and 31% of the material recovery facilities have stopped/reduced their process in the UK and US respectively (theconversation.com).

2.4. Impact on noise levels

A remarkable drop in the level of noise has been noticed during the lockdown period. All time busy roads, which would constantly get noise pollution from horn honking and vehicular whirr, are completely quiet now. Machinery clanking, too, has stopped substantially in Industrial districts. Global data shows that the traffic movement is down by 54, 36, and 19% in the United Kingdom, United States, and China respectively.

The reduction in anthropogenic seismic noise is very important for the seismic sensors to detect micro-tremors and smaller earthquakes. Cultural- or ambient-noise associated with human activities is ~1 hertz and above, while the standard frequency at which earthquake energy comes in is at 1 hertz. Decreased economic activity during lockdown has brought down the detection threshold resulting in increased earthquake detection (The Economic Times, 2020). In big cities that are considered high-risk earthquake zones, like Los Angeles, data during lockdown is particularly useful. In Canadian cities like Montreal, Ottawa, and Calgary noise dropped by more than 40%, 33, and 60%, respectively (CTVNEWS, 2020). Curtailment of boat- and shipping-traffic had plummeted ambient oceanic noise across the world, which creates better conditions for marine life. Real-time measurement of underwater sound signals showed a remarkable drop in low-frequency sound that is often associated with ships (Ian Randall, 2020).

As most of the international flights are cancelled, and domestic travel has also become very slow, air traffic dropped significantly as well. Both culturally and economically, Europe and North America are closely linked and therefore the airspace connecting the landmasses is tightly filled. Fig. S4 shows two snapshots of the same airspace over the Atlantic Ocean—28 days apart (on 2 March 2020 and 30 March 2020). The consequences of the air traffic and hence the noise pollution can easily be seen from the picture.

In India, airports/bus-stands/train-stations handle ~7800 flights daily, ~528,333 buses, ~13,452 passenger trains and ~9141 freight trains run daily, respectively (Business standard, 2020); of which a minimal fraction of air traffic and freight trains are running during COVID-19 lockdown. The live monitor on Indian Railways’ dashboard, India’s biggest national transporter at ~22 million passengers per day, displayed zero passengers or mail express trains under operation on 22 March 2020 10:00 PM IST, for the first time in transporter’s history (Dutta, 2020). With this cessation of trains comes an abrupt drop in sound associated with train horns (for which maximum and minimum volumes permitted are 100 and 96 dB, respectively (Singh, 2020),
operation of train etc. With national lockdown, the use of private and commercial transportation, which was attributed to be one of the largest sources of noise in Indian metropolises (Mishra et al., 2010), has also decreased drastically. Suburban trains of Mumbai, which emanate high noise levels in cities’ corridors (highest recorded at 97.7 dB near Mahim railway junction (TOI, 2020c)) are completely halted due to lockdown. Policies towards social distancing by various ministries brought down the noise that emanates during commercial events, marital and/or religious processions to negligible levels.

Based on the data evaluated from the five automatic ambient noise measurement stations located across Kolkata, noise pollution was reduced by 50–75% during the lockdown (LI) (Jayanta Basu, 2020). Noise measurements by Karnataka Pollution Control Board (KSPCB) in BTM, Silk Board and JC Road areas (which have high traffic density during office hours) of Bengaluru are < 45 dB even during daytime (Thakur, 2020). This drop is accredited to halt on construction and transportation. Certain areas of Delhi showed a reduction in the noise level by 40–50%. Observations from Govindpuri metro station in Delhi had revealed that, due to reduced vehicular transport, the sound levels have reduced to 50–60 dB, against 100 dB noted during normalcy (Gandiok and Ibrar, 2020). Box-plots in Fig. 5 show the noise quality data from four metro cities of India before and during the lockdown period. It can be seen that 15–25% in the intensity of noise reduction was observed during the lockdown period.

2.5. Impact on GHG emissions

Latest data from the world meteorological organization (WMO) indicates that greenhouse gas (GHG) emissions in the atmosphere rose to a new record in last few years. Carbon dioxide (CO2) emissions were 18% higher in the last five years (2015 to 2019) than the previous five years (2010–2014) (Global Climate report, 2019). It is estimated that the emissions over the past 50 days from the world's largest carbon emitter (i.e., China) lowered by about 25% compared to Pre-COVID-19 (nationalgeographic.com). As per the International Energy Outlook (2019) report, 64% of electricity energy comes from fossil fuels (coal, gas, and oil: 38, 23, and 23% respectively).

The International Energy Agency has forecasted that the emission of CO2 could fall by 8% (equivalent to 2600 Mt. CO2) during this global lockdown (Scientific American, 2020). Some forecasters have also expected the emissions to fall by more than 5% in 2020, the greatest annual reduction so far. But it’s still short of the 7.6% decline that is needed every year over the next decade to stop global temperatures from rising more than 1.5 degrees Celsius (Scientific American, 2020).

Fig. 6 compares the reduction in CO2 emissions during the present crisis with the past major events/pandemics. It can be clearly seen that the maximum drop in the emission of CO2 emissions has been observed so far during the COVID-19.

Implementation of uniform and austere lockdown helped GoI control the transmission rate of COVID-19, but it also led to sharp reduction in human activity. This drop complemented with preexistent economic slowdown and increase in the generation of renewable energy resulted in ‘India’s first year-on-year (YoY) reduction of CO2 emissions in 4 decades’. Collective national CO2 emissions dropped by ~15% during March and likely to have dropped > 30% in April (Myllavirth and Dahiya, 2020). National power consumption of India descended up to 20% relative usual conditions, just 10 days in to the lockdown. Based on the daily data from the national grid (POSOCO daily reports; https://posoco.in/reports/daily-reports/), the coal-fired power generation (which was established to be the biggest GHG emitting sector of India) dropped by 15% and 31% in March and first 3 weeks of April 2020, respectively. Fig. S5 presents India’s power generation trends (total and coal-based daily power generation, relative previous years), during the lockdown. Similar to electricity demand, the consumption of oil and natural gas also decreased during COVID-19 lockdown. Due to truncated demand during the pandemic transmission phase, compounded with already slower demand growth earlier in the year and commotion in international oil/gas markets, oil utilization and natural gas consumption in India fell by 18% YoY in March 2020 and 15–20% during the lockdown, respectively (Myllavirth and Dahiya, 2020).

While many studies speculate on the drastic reduction in the carbon emissions in the past few weeks, there exists another set of data that suggests a trend of ‘sharp rise’ in global carbon dioxide (CO2) levels during the lockdown. In April 2020, the average concentration of CO2 in the atmosphere was 416.21 ppm (ppm), the highest since measurements began in Hawaii in 1958 (UNEP, 2020). Fig. S6 compares the emission of CO2 in the atmosphere of the last decade, it can be easily seen that the emissions have not decreased during the first four month of 2020. Although vehicular and air traffic, and industrial activity has reduced sharply in most parts of the world since January 2020, this is not the case with electricity supply. Heating systems have been functioning as before COVID-19. None of the fundamentals (such as the shift to renewable energy, deforestation, etc.) have changed; but the investments/capital-infusion into capacity building of renewable energy will get impacted in the short term.

According to the market report published by the international tropical timber organization (ITTO), rapid spread of COVID-19 and associated drop in economic activity has severely impacted timber sector in tropical countries (including India) (ATIBT, 2020). This reduced demand and lockdown restrictions has temporarily halted the long-planned wood harvest, which, in turn, lead to reduced release of CO2 (in form of lost carbon emissions).

According to Ramachandra (2009), the carbon emissions from road-based, rail-based and aviation transportation were estimated to be 243,816, 5223 and 7608 Gigagram (Gg), respectively. Since then, the number of motor vehicles has been growing at an average rate of 8–10% per year (MoSPI, 2020). Because of the unavailability of the latest data, it can be only estimated that the emissions in 2019 from road transport alone were 300% greater than the value reported by Ramachandra (2009). Owing to the present lockdown situation, all
major transportation activities have been stopped (except freight carriers and special transportation approved by the government). It can be anticipated that a majority portion of emissions are likely to be reduced during this period.

**3. Environmental sustainability and future perspectives of COVID-19 lockdown restrictions**

The current COVID-19 situation has taught us what we, as the human population, will have to do in order to manage and conserve the planet’s ecosystems from the future inevitable environmental crises. The major findings relating the sustainability of environment as a result of lockdown restrictions are listed below:

a) Owing to the course of lockdown of transportation, industrial activities amid the coronavirus outbreak, most of the pivot pollutant concentrations in the ambient air decreased significantly. The contrary, indoor air quality adverse during lockdown period.

b) Data pertaining to river water quality before and during lockdown exhibited remarkable differences in strength (or characteristics) of flowing water. Water quality of river Yamuna at some locations even satisfied drinking water quality standards of BOD. Nevertheless, continuous release of domestic wastewater and its confluence with freshwater decreased DO level at several locations too. Overall, such improvement in river quality could reinforce attempts to be pursued by authorities to implement water quality preservation schemes in more prominent and effective manner during the post-pandemic recovery period.

c) Based on the availability of limited data, it can be concluded that the generation of MSW has reduced significantly; however, a drastic increase in the generation of BMW, plastic waste is observed in the past few months. A massive reduction in the recycling of waste has been found as a major obstacle in the circular economy approach. Managing BMW during this crisis has been identified as a big challenge to the local civic authorities.

d) It can be stated that noise pollution caused due to human activities have decreased in the past couple of months. This can be considered as a good time for nature to revitalize itself. Human beings will also agree that instead of living in the constant assault of the noise generated by the modern society, these quieter times actually have a calming effect.

e) A mixed opinion about the emission of carbon dioxide is reported. Many investigations/reports have suggested the emission of CO₂ could fall by 5–8% during the lockdown period. However, a recent report published by UNEP indicates that the CO₂ emissions are rising sharply during the lockdown period.

Almost all the major countries, including India, have observed a halt in transport (ground, rail-based and aviation), construction activities and human movement, which led to a sharp decline in anthropogenic emissions and noise levels, and improvement in water and air quality. Several animals (Olive Ridley turtles were seen nesting during daytime on an Odisha beach after 7 years), fish (South Asian river dolphins returned to Kolkata ghats after 30 years) and bird species (migration of ~25–30% more flamingos compared to last year in Talawe wetland, Mumbai) were seen returning to their natural habitats (Katariya, 2020). However, the sudden activation of all the human activities in future (post-lockdown) holds the possibilities of spike in emissions and overall pollutant concentrations nationwide. Since the disease is still spreading across the globe, people are still facing lockdown restrictions, and the restricted data is not yet available, nothing can be deduced clearly at the time. But, decrease in environmental pollution as a result of coronavirus restrictions will surely compel government bodies, scientists, legislators, autonomous authorities and other regulatory agencies to use the resources sensibly.

As the stratagem against COVID-19 is being pre-emptive, policy makers have to map all possible future scenarios for better handling of public health and judicious use of available assets/appropriations. Until an accepted vaccine is developed, the only deterrence against SARS-CoV-2 is national/regional lockdown accompanied with social distancing. GoI has provided relaxation of numerous lockdown measures in its current phase of lockdown (L5), which brought in an increased anthropogenic activity relative to previous phases (L1, L2, L3 and L4); due to which, India is seeing an abrupt increase in number of COVID-19 infections. While Indian Railways (IR) had already announced resumption of 200 non-AC trains from 01 June 2020, GoI has allowed airlines to operate in certain corridors from 25 May 2020. These decisions have aggravate the aforesaid context of increase in infections.

COVID-19 has helped the populace realize the opportunities and need of research potential in the field of protection accessories (masks,
gloves, PPE etc.) used during the pandemics. Normal surgical masks do not survive for more than two hours (Kelkar et al., 2013). Some of the research opportunities for the textile sector include the development of advance, reusable and washable masks, PPE, gloves with high antibacterial property, special coating etc.

Not everything is negative about the COVID-19 situation. The positive responses received in terms of global/regional environmental health are a motive to be optimistic and anticipative in the present scenario.

4. Conclusions

COVID-19 (and its associated disarray of events) is a dress rehearsal for dealing with climate change in the future. Some of the major effects of this pandemic on the environment after the initial days of lockdown in India are summarized in the current article. The present study identified the pros and cons of COVID-19 on the environment in terms of improvement of ambient air quality, surface water quality, reduction in the MSW generation, noise pollution and emission of GHGs. The negative effects on the environment in terms of increase in the BMW generation, mixed effect of carbon dioxide emission have been observed.

CRediT authorship contribution statement

Mohit Somani: Conceptualization, Writing - original draft, Investigation, Resources, Project administration, Writing - review & editing. Abhishek N. Srivastava: Writing - original draft, Validation, Supervision, Visualization, Resources, Writing - review & editing. Shiva Kumar Gummadivalli: Writing - original draft, Data curation, Investigation, Visualization, Formal analysis, Writing - review & editing. Aparna Sharma: Writing - original draft, Project administration, Validation, Writing - review & editing.

Declaration of competing interest

The authors declare no conflict of interest.

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Appendix A. Supplementary data

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