Spike in pollution to ignite the bursting of COVID-19 second wave is more dangerous than spike of SARS-CoV-2 under environmental ignorance in long term: a review

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Abstract

Specific areas in many countries such as Italy, India, China, Brazil, Germany and the USA have witnessed that air pollution increases the risk of COVID-19 severity as particulate matters transmit the virus SARS-CoV-2 and causes high expression of ACE2, the receptor for spike protein of the virus, especially under exposure to NO₂, SO₂ and NO_x emissions. Wastewater-based epidemiology of COVID-19 is also noticed in many countries such as the Netherlands, the USA, Paris, France, Australia, Spain, Italy, Switzerland China, India and Hungary. Soil is also found to be contaminated by the RNA of SARS-CoV-2. Activities including defecation and urination by infected people contribute to the source for soil contamination, while release of wastewater containing cough, urine and stool of infected people from hospitals and home isolation contributes to the source of SARS-CoV-2 RNA in both water and soil. Detection of the virus early before the outbreak of the disease supports this fact. Based on this information, spike in pollution is found to be more dangerous in long-term than the spike protein of SARS-CoV-2. It is because the later one may be controlled in future within months or few years by vaccination and with specific drugs, but the former one provides base for many diseases including the current and any future pandemics. Although such predictions and the positive effects of SARS-CoV-2 on environment was already forecasted after the first wave of COVID-19, the learnt lesson as spotlight was not considered as one of the measures for which 2nd wave has quickly hit the world.

Keywords Future pandemics · Future waves of COVID-19 · Pollution spike · Spike protein of SARS-CoV-2 · Total environmental management · Waterborne COVID-19

Introduction

All viral pandemics usually exhibit multiple waves (Maragakis 2021; Róka et al. 2021). The intensity of the contagiousness of viral pathogens depends on numerous factors (Tayech et al. 2020). However, subsequent waves of pandemics can be prevented using preventive measures.

Vaccination, social distancing, hand sanitization practices and use of face mask have been considered few of the main approaches to prevent the outbreak of COVID-19. Above steps can be taken at individual level, and lockdowns and shutdowns are few of the government approaches that were employed to break the chain of the virus SARS-CoV-2. Complete or partial failure to adapt above approaches is considered to be the main reasons why many countries including Kyrgyzstan, Australia, South Korea, Israel, New Zealand, India, Japan, Spain, the UK, the USA and Iran have witnessed the 2nd wave of the disease (Dargahi et al. 2021a, 2021b; Sarailoo et al. 2021; Vosoughi et al. 2021; Zandian et al. 2021, Fig. 1). Although about 3,839,816,037 people have been vaccinated against the viral disease as on 2 August 2021, some or many of the failure preventive measures are responsible to raise the total number of infection by SARS-CoV-2 to 198,022,041 out of which 4,223,460 lives has been swallowed by the virus as on 2 August 2021 (WHO 2021).

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Fig. 1 Global status of the first and second wave of COVID-19 outbreak by the mid-April 2021. The first wave (red arrows) seemed to be decreased to its lowest value by the end of December 2020, while the second wave (purple arrows) has been started almost in all countries and now been observed to move with full speed of contamination. Although most of the countries have experienced the peak of the first wave between

June 2020 and December 2020, the second wave is hitting almost all the countries at this time point. Still the trend of COVID-19 infection per million population is high in America, followed by Europe, Asia, Eastern Mediterranean countries, Africa and Western Pacific regions. Numbers of infection has been shown in inserts (Source WHO 2021 under creative common attribution)

After adapting stricter actions such as vaccination, lockdowns, and other associated health measures, few of the above countries have successfully defended the 2nd wave, but many countries such as India have been battling hard to control the

infection and death under the disease (Fig. 2). India had won the war against COVID-19 when its 1st wave hit the country in approximately March 2020 (Coccia 2021; Das and Paital 2020; Das et al. 2021; Paital 2020; Paital et al. 2020a, b;

Fig. 2 Real-time data for the total number of cases verses the total number of deaths in India in COVID-19 up to the last week of April 2021. Data indicate that the peak in both death and infection rate was observed in the country during August to September 2020, and then the graph took a long jump in linear scale in March to May 2021 (Worldometers, 2021)

Sarkodie and Owusu 2021). The 1st wave had given enough experience to each country to use the learnt lesson as spotlight for the prevention of the 2nd and subsequent waves of COVID-19 (Mousazadeh et al. 2021). Then what made the countries to suffer so severely under the 2nd wave is the biggest question and has been addressed by many experts up to certain extend (Bhuyan 2021). Failure to set strategies for peak and non-peak timings, imbalance between demand and supply of COVID-19 logistics especially oxygen, failure to hold a planned and quick vaccination programme, and failure to take strong measures to follow COVID-19 guidelines are the reasons for which countries such as India are suffering from the disease outbreak under 2nd wave to a bigger extend (Bhuyan 2021).

The above points are the cons, but none has discussed the pro of the event in countries such as India and Brazil that strive very hard to protect their people from infection and death especially during the 2nd wave of the disease. Overall, out of the confirmed 198,022,041 infections and 4,223,460 deaths counting 2.13% fatality rate, Brazil has 19,797,086 confirmed infections and 553,179 deaths that contributed to 2.79% fatality rate (Karami et al. 2021; Pivato et al. 2021; Worldmeters 2021). Concomitantly, in India, the value is 1.34% out of the 31,572,344 total number of infections and 423,217 confirmed deaths in COVID-19 as on 2 August 2021 (WHO 2021). The criticism rose against India by the prestigious journal Nature that the country is known for ignoring its scientific advices made by experts for the prevention of COVID-19 before or during the 2nd wave and did not use the opportunities it had before hit by the 2nd wave (Editorial 2021). The main question here remained unclear that is lifting of lockdowns and unsatisfactory manhandle of COVID-19 logistics and situations had pushed the country to suffer the most? Many scientific articles have forecasted to use the lesson learnt from the 1st wave as spotlight to handle subsequent waves (Fig. 1).

Mainly, the possibility of the relation between environmental pollution especially air and water pollution and COVID-19 has been ignored everywhere (Fig. 3). Although the improvement of environment under the lockdowns is largely documented (Paital 2020; Paital et al. 2020b, Table 1), involvement of the environment to enhance the rate and severity of infection of COVID-19 has been ignored (Lee et al. 2021; Paital and Agrawal 2020; Paraskevis et al. 2021). Involvement of the environment especially air and water for the 2nd wave was predicted but was not considered by any country seriously to prevent the disease (Róka et al. 2021). Ignorance of such forecasting and environmental protection activities which could lead to the quick 2nd wave of the disease is the central focus of this review article.

The level of CO₂ has already crossed the threshold of 400 ppm, but nowhere any substantial step has been taken to prevent it. Likewise, chemical pollutions in air, water, and soil are increasing day by day that would provide a platform to

develop many SARS-CoV-2 and many potent viruses that can swipe the life of any particular species from the world very quickly. It is because the environmental chemistry is always detrimental for the development and/or survival of any, virus and this could be the reason why the SARS-CoV-2 is getting mutated very quickly when it travels (via infected human hosts) from one country to another that have different climatic (and polluted) set up (He et al. 2021). Therefore, the spike in environmental disorders including pollution must be checked for the long-term benefit; otherwise, such spike could be more dangerous in the future than the marker spike protein of the SARS-CoV-2 virus that attaches to the receptor ACE2 dominantly present on respiratory epithelial cell surface of human host. This has been discussed for the first time in this review article.

More clearly, handling the spike in pollution at several parts especially in urban and semiurban areas is more important for long-term benefits. The spike protein of the SARS-CoV-2 may be handled within limited time period with vaccination or appropriate medicines (if discovered against SARS-CoV-2 in future) or repurposing the available antibiotics, anti-malarial or anti-cancer drugs. However, many diseases including the present COVID-19 get aggravated under the spike in NO₂, SO₂ and PM_{2.5} emissions in many countries, and such diseases found to get intensified both the terms of infection and severity under polluted environments in human and non-human hosts (Paital and Agrawal 2020). In one hand, polluted environments act to diminish disease resistance capacity (by immuno-suppression, specific organ dysfunction such as lungs etc.) in hosts, and on the other hand, these also create ambient conditions for growth and propagation of many pathogens. For example, infection and severity of SARS-CoV-2 is high in human under frequent exposure to the increased PM_{2.5}, SO₂ and NO₂ emissions because exposure to all of these gases especially NO₂ and SO₂ is responsible to increase in expression of ACE 2 in human respiratory epithelial cells, and ACE 2 acts as receptor for the spike proteins of SARS-CoV-2 to get attached to the host cell surface having ACE 2. Specific disease including the current pandemic COVID-19 may be handled in future after few months or years, but such environmental pollutions need to be handled for long-term benefits to avoid such pandemics or endemics. Emphasis was given to discuss the above point in this current article with an objective that it will add to the existing researches on COVID-19.

Air and water pollution verses COVID-19

Pollution acts as a general inducer of immunity reduction for all diseases including the current contagious disease COVID-19. Air, water, sound and soil pollution have been prevailing in many parts of the world above the threshold values (Paital

Table 1. Positive effects of COVID-19 after its first wave.

Events	Place of occurrence	Reason
Decreases in emissions of greenhouse gases such as NO ₂ , SO ₂ and CO ₂	Worldwide, especially 40% reduction in NO ₂ emissions in Wuhan, China. Reduction in emissions of NO ₂ by 13–44%, O ₃ by 2–20% and PM _{2.5} by 10–28% in 27 countries. Reduction of CO ₂ by 5–10% New York (USA), NO ₂ by 20–30% in China, Italy, France, and Spain, 30% NO ₂ in the USA, 40–50% of NO ₂ in India, 30–50% NO ₂ and 5–15% PM in Western Europe, 64.8% CO ₂ , 77.3% NO ₂ , 54.3% NO ₂ in São Paulo (Brazil) etc.	Reduction in vehicular and industrial operations. Less or discharge of exhaustion gases
Increase of O ₃ layer	Worldwide especially increase of O ₃ , 24% in Nice, 14% in Rome, 27% in Turin, 2.4% in Valencia, 36% in Wuhan, 20% in Sao Paulo, 50% in Barcelona, 11% in London, 17% in 22 Indian cities, 43% in Beijing-Tianjin-Hebei region and 15% in Almaty	Reduction in vehicular and industrial operations. Less or discharge of exhaustion gases
Reduction of noise pollution	Worldwide	Reduction in vehicular, flight and industrial operations
Reduction in water pollution	Worldwide, notably Vembanad Lake, River Cauvery, Ganga River and Yamuna River of India, Venice's canals in Italy, Acapulco Beach in Mexico, Rimac River in Peru, Barcelona Beach in Spain	Reduction in tourist activities and less or no release of industrial effluents
Reduction in electricity consumption	Overall 10% worldwide and 30% in Italy, 15% in France, 12% in Germany, 15% in Spain, 20% in India and 16% in the UK	Less industrial operations. Government and non-government official closing
Reduction in (fossil) fuel consumption	Less 8% in coal combustion globally, 36% less in China, 5% in Europe, North America and allied countries. Global gas consumption was declined by 2%	Less industrial and vehicular operations
Reduction in traffic	Worldwide especially reduction in 50% in New York City, 75% in Madrid etc.	Less vehicular operations

COVID-19-induced lockdowns and shutdowns have lessened pollution at many time points in the world during COVID-19 than pre-COVID-19 time under the seized or less industrial and vehicular operations. As a result, the water and air that usually get polluted from the above activities are found to be cleaned, and the pollution level in many cities has been reduced

2020; Bhargava 2021). Air pollution is known for the death of people in many countries including India (Fig. 3). CO, CO₂, NO_x, SO_x, soot especially (organic) particulate matters (PM_{2.5} and PM₁₀) and smoke are the main sources of air pollution that are usually generated from fossil fuel exhaustion by industrial, vehicular and house hold cooking activities (Paital and Agrawal 2020; Sarkodie and Owusu 2021; The World Bank 2021). The emission of CO₂ was 36.44 billion metric tons in 2018. If the trend continues, air pollution is predicted to rise manifold by 2050 (Table 2). In general, air pollutants are responsible for 2.17 million deaths in 2019 (Tiseo 2021). And the death could have risen to 6.6 million by 2020 (Hadlington 2021). A detailed description about air pollution altogether with other pollutants, associated (respiratory) health complications including the chronic obstructive pulmonary disease have been discussed in details, and therefore, prevention of air pollution must have been the prime target (Paital and Agrawal 2020).

The main aspect of air pollution with respect to COVID-19 is the relation between the expression of the receptor protein ACE2 in human respiratory cells under exposure to NO₂ and SO₂ emissions and the infection and severity in the disease. Like COVID-19, two more epidemics were observed in China and Saudi Arabia in 2003 and 2012, respectively. They were called as SARS and MERS, respectively. Interestingly, SARS was caused by a strain of the coronavirus family and was called as SARS-CoV-1. SARS-CoVs have the “spike” protein that act as receptor for interacting with the ACE2 of (non)human host (Paital and Agrawal 2020). The internalisation process of coronavirus indicates that they get attached to the cells via spike protein-ACE2 complex and release their RNA genome into the host cells. It has been established that the expression of ACE2 has a strong positive correlation with the exposure to air pollutants such as NO₂ and SO₂ (Paital and Agrawal 2020, Fig. 4). The infection and severity in COVID-19 depends on the viral load in the patient's body which could be increased with the increase in exposure to air pollution. Therefore, it is pertinent that the infection and severity of COVID-19 would be high under air pollution as observed in India and Italy (Fig. 4).

Similar could be the case with wastewater contamination by the SARS-CoV-2. Many reports have defined the presence of SARS-CoV-2 in water bodies (Medema et al. 2020; La Rosa et al. 2020; Wu et al. 2020; Wurtzer et al. 2020; Ahmed et al. 2020; Randazzo et al. 2020; Rimoldi et al. 2020; Rimoldi et al. 2020; Langone et al. 2021; Tran et al. 2021). The main source could be the release of the daily waste from the infected patients to the drainage, sewerage and finally their release without treatment to the nearest river or water reservoir (Róka et al. 2021). Therefore, wastewater-based epidemiology has been proved, and SARS-CoV-2 in its present form or in future mutated form h could be more dangerous. The robustness of the protocol followed by the above

Fig. 3 Relation between air pollution and COVID-19 status in New Delhi, India. Air pollution indices were low in August 2020 amid COVID-19-induced lockdowns in New Delhi, India. As the lockdowns were lifted, the predicted massive gas exhaustion from reopening industries, vehicular traffics, etc. was able to uplift the air pollution status (a). Again the loose lockdowns along with disobeying of COVID-19 guidelines were able to lift the gas exhaustion in February 2021. That provided a sound background for speedy infection (b), causality and mortality in March 2021. The pattern still continues in April and May 2021 (c). The

main factors such as particulate matters (PM) could be the reason to increase a sharp rise in COVID-19 infection by acting as vehicle of transmission while SO_2 , NO_2 and CO could be the contributing factor to increase the infection rate and/or severity in the disease by up regulating the angiotensin converting enzyme 2 in the epithelia cells of respiratory cells that acts as the receptor for the SARS-CoV-2, especially for its spike protein (Paital and Agrawal 2020). The raw data were collected from Bing (2021) and NAQI (2021) under creative common attribution license

researchers to measure the viral load was very high as they have quantified the N gene in SARS-CoV-2 RNA using RT-qPCR. It is observed that using oligonucleotides, real-time PCR methods are now accepted as one of the gold standard methods to study and identify the expression level of genes that act as markers for identification of SARS-CoV-2. Examples of such genes are RdRP, E and N genes. The authors established that the limit of detection of the above genes was $>10^{-1}$ (atto) M for RdRP, 10^{-1} (femto) to 10^{-1} (100 atto) M for E gene and 10^{-1} (1 to 10^{-1} (10 atto) M for N gene (Cho et al. 2020). This standard method can be used to monitor the environmental contamination to identify any emergent of more potent (SARS-CoV-2) viral strain. If agreed to the above and other similar results, a total environmental

approach is essential to save us from deadly microbes. This was predicted by Róka et al. (2021) and many others predicted too early.

Availability of the virus indicates their survivability in water. In many countries, the water hygienic condition is very poor, and people use water for their daily work including drinking from rivers and pools that are commonly contaminated with many pathogens including SARS-CoV-2. If such water is used for washing face, bathing, washing clothes and even for drinking after nominal purification (passing through multilayers of clothes), then the chance of infection could be high. This could be the reason when people get confused why they are tested COVID-19 positive although they maintain social

Table 2 Prediction model for air pollution emission in every 5-year gap up to 2050.

Pollutants	2015	2020	2025	2023	2035	2040	2045	2050
SO ₂	104.1	96.9	89	83.5	79.9	75.8	71.1	68.3
NO _x	136.7	137	141.5	146.7	154.1	165.3	169.6	175.7
NH ₃	57.1	56.8	58.5	57.6	57.7	59.2	58.6	58.2
VOCs	164.8	131.7	136.6	141	146.4	157.4	160.4	164.3
BC	5.3	4.8	5	5	5	5.2	5.1	4.9
OP	16.4	14.9	15.4	15.6	15.5	16.5	15.9	15.5
CO	1159.9	717.9	790.3	844.9	887.7	1001.4	1016.4	1035

The data are presented as million metric tons per year. Sulphur dioxide (SO₂), nitrous oxide (NO_x), ammonia (NH₃), volatile organic compounds (VOCs), black carbon (BC), organic particulates (OP) and carbon monoxides (CO) are presented in the table. Data are considered from the real-time sources for 2015 to 2020, and prediction was done after considering several pros and cons associated with the emission in global basis. The graphs are given free per click at www.statica.org by Tiseo (2021) and were converted into tabular form

distancing, sanitization and mask as preventive measures. Therefore, the proper treatment of solid and liquid wastes released from infected patients must be done before they are released to environment in general and water bodies in particular.

Pollution and COVID-19 severity, examples

Airborne

Environment has a definite role in protecting us from several diseases including the current or future pandemic (Róka et al. 2021; Roviello and Roviello 2021; Khan et al. 2021; He and

Han 2021). Sever intensity of air pollution dominant area in patches or in whole countries in China, India, Italy, Brazil and many other countries has been witnessed during pre-COVID-19 time periods (The World Bank 2021). Organisations such as WHO and many other have issued notices regarding control measures of air pollution and restriction of the water contamination by COVID-19. This fact has been supported by experimental data (Róka et al. 2021). In Italy, Spain, France and Germany, out of the initial mortality of 4443 recorded in the beginning of COVID-19 outbreak, about 78% deaths (accounting 3487 deaths) were strongly correlated with the area where NO₂ pollution was high (Ogen 2020). Similar higher rate of infection and mortality in COVID-19 was also observed in Northern Italy where air pollution was the highest compared to other parts of the country (Conticini et al. 2020, Fig. 4). For example, levels of SARS-CoV-2 virus were supposed to be high in the environment at the Po Valley of Northern Italy where both air pollution and COVID-19 were at the peak as compared to the other parts (Di-Cerbo 2020). So, air pollution was strongly suggested to be considered risky for the easy spreading of COVID-19 (Martelletti and Martelletti 2020).

Similar link between epidemics caused by SARS-CoV-1 in China in 2003 was also positively correlated with air pollution (Li et al. 2017, 2018, 2020). The observed association between air pollution and COVID-19 was pushed organisations such as WHO, who had earlier rejected the theory of airborne nature of COVID-19 till late 2019 and finally had declared COVID-19 as airborne disease in late 2020 (Chen et al. 2021a; WHO 2020). Therefore use of multi-layered mask to prevent infection from the exclusive viral circulation in air during its 2nd wave has been suggested. Special measures should be taken in areas predominant with NO₂ pollution due to its strong association with ACE2 expression (Fig. 4). This idea seems to be employed globally for the prevention of observed 2nd or subsequent waves of the disease (Fig. 5). Similarly, 0.38% higher mortality could also be noticed with an increase

Fig. 4 Relation between environmental NO₂ concentration and COVID-19 infection and death rate in Italy. Data indicates that a strong and positive correlation observed between environmental NO₂ concentration and COVID-19 infection and/or severity and death rate in Italy. The reason being contributed to the upregulation of the angiotensin converting enzyme 2 in the epithelia cells of respiratory cells that acts as the receptor for the SARS-CoV-2, especially for its spike protein (Redrawn after Ogen (2020) under creative common attribution license. Paital and Agrawal 2020)

Fig. 5 Global view of the second wave of the COVID-19. **a** Total number of the confirmed COVID-19 cases as on May 2021. **b** Total number of the confirmed death in COVID-19 cases as on May 2021. Two clear peaks are observed between October 2020 and November 2020 both for the infections (nearly 5 million cases per 100 million populations) and death (nearly 90 thousand per million populations) in COVID-19 in the first wave (red arrows). In the 2nd wave, an increasing trend has been observed, but it is not clear when the peak will arrive (blue arrows)

of 10 mgm^{-3} of $\text{PM}_{2.5}$ in polluted area, although other pollutants such as SO_2 , CO and CO_2 along with ground level O_3 are also found to induce severity in this contagious disease (Fig. 6, Li et al. 2017, 2018, 2020). It suggests about the urgent need to control air pollution as one of the most reliable strategies to prevent COVID-19 severity.

India is the country who had managed well to keep very low mortality rate per her high number of million people infected from COVID-19 (Paital et al. 2020a, b). In March 2021, India, especially its capital Delhi, has fought very hard with the 2nd wave of COVID-19 with multiple strains. Situation at other metro cities of India such as Mumbai and Calcutta was also similarly worst. The contemporary pollution level had a clear relation with the COVID-19 cases. The concomitant wavy graph observed both for air pollution and COVID-19 spikes in the case of New Delhi India up to May 2021 hints about the need of a strict control measure against air pollution (Figs. 2, 3). The country's overall air quality value was 800, being the worst in the world as compared to the 300 to 600 values documented for the other worst air stations in different countries during May 2021. At the same time, the value was also between 1 and 10 in some of the best air quality stations of the world such as North West LLS Moree, Western LLS Tibooburra, Floyd Dryden, Alaska, Olav V gate, Bodo, Norway, Cayenne Caiena 3, Guyane, France and Albany during May 2021 (AQICN 2021). As per the data of the above organisation, India, China, Magnolia and Tajikistan had sequentially topped the rank with air quality index of 209, 201, 190, 176 and 164, respectively on 2 May 2021 (AQICN 2021). Concomitantly, the infection rate of

COVID-19 was also drastically low or nil at such places. It clearly suggests that the air quality along with the medical facility needs to be improved to give check-mate to COVID-19 from its 2nd wave and also from the upcoming waves.

The central and state governments of India had imposed strict lockdowns in the state; as a result, many environmental improvements were noticed, for example, as observed in the capital of India during its 1st wave of COVID-19 (Paital 2020). Without vaccination, the country and its capital had able to defend the disease quite efficiently in an unseen manner with only using drug repurposing care and imposing social distancing and allied preventive measures against COVID-19. However, once the government had lifted the lockdowns and allowed opening of industries and allied activities, a spike of air pollution was observed to be faster. And it could be one of the reasons for the observing high spike in pollution with a deadly entry of the 2nd wave of the disease (Fig. 7). Although multiple waves are common in contagious pandemics, such serious and more potent viral infection was unexpected during its hitting in 2nd wave and has been positively correlated with the increase in air pollution. Many reports have documented the vice versa relation, i.e. improvement of the environment via COVID-19-induced lockdowns (Maji et al. 2021; Mahato et al. 2020; Sharma and Balyan 2020, Table 1). Since the 3rd wave of COVID-19 in India is forecasted (Sharma 2021), one of the take home messages must be “to avail regenerating nature on to fight better against the disease” (Paital 2020; Róka et al. 2021). So, by accessing clean air (Paital 2020; Paital et al. 2020a, b; Paital and Agrawal 2020) or by restricting the wastewater-based epidemiology of the current pandemic, India could fight better against the 2nd wave of COVID-19 (Róka et al. 2021).

Water contamination with SARS-CoV-2

Similar to the airborne nature of COVID-19, water contamination and pollution with its causative agent, i.e. the RNA of SARS-CoV-2, were also noticed in wastewater and reservoirs (Singh et al. 2021). Basically, water source is contaminated from the wastewater released from COVID-19 hospitals/care centres and from households where home isolation of infected people is adapted. If the wastewater from such sources is released without treatment to any water sources, RNA of SARS-CoV-2 present in the cough, stool, urine, faecal matter, etc. of infected people that carry the RNA is believed to contaminate water bodies. It has been predicted early by many including Róka et al (2021). The first report that describes about the presence of the RNA of SARS-CoV-2 in water was in the Netherlands in March 2020 (Medema et al. 2020). Then, half numbers of water samples out of the total twelve influent sewage collected from the Wastewater Treatment Plants in Milan and Rome, Italy was tested positive for the presence

Fig. 6 High risk of the COVID-19 infection under air pollution especially under the high NO_2 and $\text{PM}_{2.5}$. It has been studied that the $\text{PM}_{2.5}$ from the infected patients can carry the virus up to certain distance and the virus can be viable up to few days. The ACE2 present mainly in the respiratory tract of humans acts as the receptor of spike protein (S that breaks to S1 and S2 once it get attached to ACE2 of host) of the virus gets upregulated under NO_2 exposure. Therefore, both $\text{PM}_{2.5}$ carrying the virus and NO_2 when inhaled, they can work synergistically to increase the risk of

infection in human. On the other hand, air pollutants such as NO_2 and SO_2 are known for their immunoreduction capacity in human. Therefore, once the viruses enters through $\text{PM}_{2.5}$ or via other droplets, NO_2 and SO_2 can be responsible for the internalisation of the virus increasing the chance of severity in the patients. The step-by-step possible mechanism is demonstrated (adapted from our previous article Paital and Agrawal, 2021 under creative common attribution license)

of the SARS-CoV-2 in April 2020. The test was done with a high precision molecular test with specific primers (La Rosa et al. 2020). Subsequently, similar reports were documented from Massachusetts, USA, in March 2020 (Wu et al. 2020); Paris, France (Wurtzer et al. 2020); in Brisbane, Australia (Ahmed et al. 2020), Region of Murcia, Spain (Randazzo et al. 2020); Milan Metropolitan Area, Italy; and Switzerland (Rimoldi et al. 2020), during March to April 2020 although the copy number or cycle threshold value in RT-PCR test was different at different places (Rimoldi et al. 2020). The same was reported in Hong Kong, China, in 2003 during SARS epidemics (McKinney et al. 2006). Subsequently, detection of the active viral RNA in river, lakes, groundwater, drinking water reservoirs, recreational water utilities and wastewater has been reported worldwide especially in countries that

utilises adapt less or no hygienic knowledge, technology and approaches (Langone et al. 2021). Therefore, the water transmission of COVID-19 is quite clear.

Lack of knowledge or adaptation of the standard cleaning and disinfection procedures along with removal or killing or inactivation of microbiota in wastewater could be the contributing factors (Kitajima et al. 2020; Romano-Bertrand et al. 2020). The source usually belongs to excreta, urine and mucus during sneezing of infected patients, wastewaters from COVID-19 hospitals, sewage sludge, etc. The mechanism of faecal-oral, faecal-fomite or faecal-aerosol/droplet transmission of SARS-CoV-2 is now accepted (Sun and Han 2021; Amirian 2020; Xiao et al. 2020). It is because similar observations were also noticed in the case of SARS-CoV-1 in China during 2003 (Wang et al. 2005; McKinney et al.

Fig. 7 Severity of COVID-19 under industrial and vehicular activities. Under the high industrial and vehicular traffics, air pollutants such as NO_2 , NOX , $\text{PM}_{2.5}$ and SO_2 and CO can decrease the immunity and increase the chance of infection and/or severity of COVID-19. Mainly, the virus can increase the lung fibrosis decreasing the chance of survivability of the patients. The relation that exists among air pollutants, ACE2 expression

and reduction of immunity can increase the lung fibrosis that positively correlated with mortality rate in COVID-19 (Adapted after Paital and Agrawal, 2021). Lifting of lockdowns and high industrial and vehicular activities to make up the loss incurred during the first wave of COVID-19 could be the deciding factor. So, environmental policy to check pollution especially air pollution is suggested

2006). Therefore, in future, COVID-19 may also be accepted as waterborne disease if the current strains or any of its mutant forms will fulfil all the criteria to infect people (Dai et al. 2021). It is because only detection of virus via water bodies may not be sufficient to declare it as waterborne communicable disease.

In India, the wastewater surveillance also indicated SARS-CoV-2 contamination, and therefore, different models were put forth to combat the disease (Sivakumar 2020; Saadat et al. 2020). Major portion of Indian population resides in rural area, and most of them have minimum idea about the health hygienic issues especially drinking water hygiene, and therefore they contract many diseases (Viswanathan and Kumar 2019). Several religious belief and actions (such as Kumbha festival allowed 3.5 million people at Uttar Pradesh during the 2nd wave of pandemic and no one was found with mask and no one was found to follow COVID-19 guideline in the

festival, Khare 2021) also manifest such activities (Vortmann et al. 2015). Water bodies of many rivers that are strongly correlated with religious belief such as the human rebirth after consumption of raw water of Ganga and Yamuna rivers are bright examples in the country (Rani et al. 2014). Scientifically, such water bodies home for many infectious microbes and infection have been detected after consuming Ganga water directly with religious mood (Vortmann et al. 2015). Dead human bodies are flown in Ganga River with belief to get rebirth or for booking place in heaven after death. Recently, under the high peak of COVID-19, dead bodies within polythene kit have been detected in Ganga River although the government did not identify about the source and cause of the deaths (under COVID-19?) under any infected disease (Pandey 2021). Under such conditions, the easy environmental transmission of COVID-19 cannot be ruled out in India.

Fig. 8 Total environmental approaches for handling COVID-19. It has been noticed that the SARS-CoV-2 virus can emerge to air, water and soil via sneezing, talking, singing-like activities, faecal and urine of patients from self-quarantined houses and hospitals and via insect vectors. The

contamination of above spheres can be seen in a cycling manner, and the cycles continue if sanitization like water treatment, air filtering and fixing pollutions along with vaccination is not done

Environmental issues exist worldwide including India. Different environmental troubles observed in the air (historical CO_2 , NO_2 and NO_x , SO_2 , $\text{PM}_{2.5}$, PM_{10} emissions, e-waste generation, carbon emissions from fossil fuel and cement, exposure to household solid fuel pollution, deaths from air pollution), water (oil spills worldwide, oil tanker disasters, the lowest access to drinking water, arsenic contamination in drinking water, water contamination with micro plastic and plastic derivatives, waste accumulation) and soil (municipal solid waste, e-waste generation and disposal, generation of plastic, dump sites management) can have obvious impacts on COVID-19 (McKinney et al. 2006; Tiseo 2021; Langone et al. 2021; Rimoldi et al. 2020; Kitajima et al. 2020; Romano-Bertrand et al. 2020). India has already been criticised for not obeying the scientific advices to control COVID-19 (Bhuyan 2021). Such troubles are evident in India, as examples are well documented in its metro cities such as New Delhi and Mumbai. Therefore, establishment of stricter national

environmental policies and their execution in general and in her metro cities in particular is suggested.

Soil contamination with SARS-CoV-2

As per the data of UNICEF, open defecation is still an issue although India has declared on 2nd October 2012 that all the villages in the 36 States and Union Territories are open defecation free (The Hindu 2021; UNICEF 2021). Open defecation practice is also followed in the case of township area by many uneducated people in India and in many other countries that could lead to the contamination in the total environment especially soil in the area (Sun and Han 2020). Therefore, the faecal matter, urine and other waste like mucous during sneezing from the infected patients could reach the soil and the virus can find a suitable micro or macro host to remain in the soil. Although such studies are not done but infection from waste of patients cannot be

Fig. 9 Several basic air cleaning methods used in air polluting industries or even in vehicles. Aerosols or particulate matters present in the air found to be the main contributing factor for the airborne nature of the SARS-CoV-2. Along with use of the advanced air purifiers in houses, but the major air polluting contributors such as in industry and associated sectors must use cyclonic dirty separator (a air is circulated with speed to settled down dirty particles), trajectory separator (b air is moved in projectile so

that dirty particle can be settled down), simple filtering bag with lower mess size and high filtering capacity (c), gravity separator (d air is allowed in a chamber to settle down the heavier particulate matters before they are released), scrubber (e special liquids can be used to absorb the dirty particulate matters) and electrostatics separated (f electric plates are used to separate the pre-charged particulate matters) to clean air before they are released into atmosphere

ruled out as the faecal matter and urine of the patients are found to carry the active viral RNA in them (Heller et al. 2020).

Current and future pandemics under environmental ignorance

Although the environmental transmission of SARS-CoV-2 was debatable initially, the wastewater surveillance has proved the fact in late 2020 and the concept must be accepted

(Dai et al. 2021). Early detection of SARS-CoV-2 in solid waste, water and atmosphere has been noticed, and the role of the total environment, i.e. air, water and soil, has been studied, and the attribution of such environmental factors to the transmission of the virus has been accepted (Fig. 8, Heller et al. 2020). Mode of transmission via the environment and the risk of contracting the disease have been linked to the quality on viral infectivity and viral load. The model of faecal-oral or bio-aerosols although advocated it lacks robust evidence, but the possibility is never denied (Huraimel Al et al. 2020). Rather it is strongly advocated that the main three primary

Fig. 10 Total environmental approaches to avoid severity of subsequent COVID-19 wave and any future pandemics

routes of transmission of the virus from faecal matters may be via water, to surfaces or to places occupied with insect vectors. Therefore, ignoring the environmental pollution may lead to a devastating state by the present or any future SARS-CoV-2 strain or its mutants or by similar and/or more potent viruses (Paital and Agrawal 2020; Dai et al. 2021).

The environmental changes have always acted as biggest power to mutate the genome of organisms including human beings (Zamai 2020). The genome of microbes has always shown its susceptibility to quick mutation under the climatic changes especially under pollution (Zhang et al. 2019). Studies from the last 2 decades have shown that heavy air pollution also triggers many molecular mechanisms including methylation, and gene editing responsible to mutate many genomes and water pollution (having molecular active pollutants including carcinogens and pathogens) has also imposes similar effects (Vineis and Husgafvel-Pursiainen 2005; Somers and Cooper 2009; Zanobetti et al. 2011; Santibáñez-Andrade et al. 2017; Rider and Carlsten 2019; Gruziova et al. 2019). Pollution also affects several biochemical and molecular pathways ranging from mitochondrial energetics to modulating mitochondrial DNA pattern (Breton et al. 2019).

Internationally, almost all countries had lifted lockdowns and allowed international movements by the end of 2020. It allowed the virus SARS-CoV-2 to travel across each corner of the world via infected people where it gets exposed to many harsh environmental conditions including pollution. This is the reason why at least six strains of the SARS-CoV-2 had been observed by the end of August 2020. Many of them are with new pathogenic characteristics and high severity of infection that resulted into high mortality rates (Università di Bologna 2021). Single-nucleotide variants in the SARS-CoV-2 spike receptor-binding domain protein were predicted to be responsible to emerge the virus for its dominant lineage harbouring the S477N receptor-binding domain mutation as seen in Australia in 2020 (Chen et al. 2021b). It has been warned that the single-nucleotide polymorphism could allow at least 143 variants of the virus which could make difficulties to tackle them all with the current treatment schedule (Giovanetti et al. 2021). So, spike in pollution could impose the spike in mutation in SARS-CoV-2 that could result in their high virulent capacity (Ufnalska and Lichtfouse 2021).

Following the pattern of evolution of the virus, countries such as India and those struggling with the hard hit of the 2nd wave of the virus have already predicted for its 3rd wave (Zheng et al. 2021). And, the potential for the severity was announced to be many folds as compared to its first two waves (Sharma 2021). If such climatic issues persist, it has been predicted that around 1 million organisms will be extinct in the next decade and it also can lead to activate about 1.7 million viruses which are enough potent to establish many such pandemics (IPBES 2021). And, it is possible that the human race can be one of the extant species in coming years (IPBES 2021). Hence, keeping environments free from pollution must be done under the present and future climatic changes. It will allow survivability of human beings and other organisms on the earth.

There are several approaches discussed elsewhere to avoid air (Leutert 1986; Hilpert et al. 2019; Bhargava 2021; EPA 2021) and water pollution especially for the treatment of wastewater to get rid of the virus (Wu et al. 2021). Many conventional non-expensive and techno-mediated measures are available to clean water and air (Jackson and Lines 1972; Iriti et al. 2020). Different adsorption (Peterson et al. 2016), chemical (Zhao et al. 2016), biological (Zhang et al. 2015) and physical technologies for the removal of NO₂, SO₂, NO_x and similar toxic gases can be employed at the emission sectors (Iriti et al. 2020, Fig. 9). A clean environment can prevent many diseases and disorders and balance the ecosystems as it was observed during the 1st wave of COVID-19 (Geary et al. 2020, Table 2). Statistical analysis has revealed the fact that a strong positive correlation between air pollution and COVID-19 infection, severity and morbidity exists in Italy, the USA, the Philippines, Denmark, Chile, Brazil, Mexico, India, China, Peru and in many other countries. For example, in the USA, 15% more morbidity in COVID-19 has occurred in areas dominated with fine-particle pollution. Similarly, a significant 12 and 4.5% higher death rate was observed in COVID-19 infection in Lombardy and Emilia Romagna regions of northern Italy that experience more air pollution. Therefore, environmental action and execution in interdisciplinary mode are required from the policy-makers and environmentalists to prevent a big loss to the earth ecosystems in the name of industrialization and modernization (Das and Paital 2021).

Conclusion

The approaches must be interdisciplinary taking the views of all sections of people to tackle the pandemics. Then expert's analysis must be done to adapt regional, national or international specific rules to revive the nature in order to survive from the current and any such future pandemics (Fig. 10). The spike in environmental pollution could be more dangerous in the near future. Increasing industrial activities for human comfort is good but extremely bad

when it is done at the cost of polluting nature. No one knows if nature will engineer more potent virus than SARS-CoV-2 to protect herself and to protect every ecosystem and their inhabitants at the cost of human race. Nature never allows a single dominant species in the earth as seen in the case of the dinosaurs and many others in the past. Therefore, national and international policy-makers need to work in collaboration with the environmentalists to formulate and implement stricter environmental rules avoiding the scientific myth in the name of modernisation for human comfort. Otherwise, the spike of the environmental pollution could be more dangerous than the spike protein of the SARS-CoV-2 for which the ongoing outbreak of the COVID-19 is persisting. Spike in environmental troubles could welcome more dangerous pandemics than COVID-19 in the future, or it can also make the current pandemic more furious in its future waves that are clear from the current condition observed in Indian and many other counties where pollution is predominated.

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Author contribution BRP designed the review outline, collected and analysed data, did statistics, interpreted the data regarding the environmental parameters and wrote the MS. KD had conceptual contribution for the study, has analysed the data, writes the MS and proofreads the MS.

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