*J. Indian Water Resour. Soc.,*
*Vol. 42, No. 2, Apr., 2022*

# MONSOON RAINS AMIDST THE COVID-19 (CORONAVIRUS) PANDEMIC – A POTENTIAL CONCERN

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## ABSTRACT

*The cause behind the ongoing COVID-19 pandemic is a deadly Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2), which belongs to a family of viruses that has a history of outbreaks in 2003 with SARS-CoV and 2012 with the Middle East Respiratory Syndrome MERS-CoV. The potential modes of transmitting SARS-CoV-2 have been identified as direct contact, respiratory droplets, and aerosols. Now the studies are coming from different parts of the world identifying the traces of SARS-CoV-2 in water bodies. Some studies are also predicting the spread of COVID-19 through water. It could be a big matter of concern to the countries with approaching south-west monsoon. This article reviewed the facts related to the potential spread of COVID-19 through water and the disease outbreak caused by floods in the past. An RBG model study using ImageJ software was done to check the geographical effect of population density and rainfall received during March to August months in different states of India. The model depicted a geographical correlation in the rainfall and population density on the spread of COVID-19 in India. Thus a mitigation strategy must be made to combat COVID-19 in such countries by keeping in mind the approaching monsoon season.*

***Keywords:*** *COVID-19; SARS-CoV-2; Monsoon; Floods; India; Pandemic*

## INTRODUCTION

Since the first index case in Wuhan, China (Chan et al. 2020)in December, 2019 the number of COVID-19 cases has reached 169 million as on May31, 2021. WHO identified the potential transmission of COVID-19 through direct contact with the infected person or object, respiratory droplets of the infected person, and through aerosols (Lee 2003).On January 30, 2020, India reported its first case of COVID-19 in the South Indian state of Kerala. A student who returned from Wuhan, China was the first index case in India. After that, all the authorities were informed and set on high alerts. All the passengers coming from different parts of the world were screened, advised to stay quarantined for at least 14 days, and monitored through the Integral Disease Surveillance Program (IDSP). An international travel advisory for restricting travel to China, Korea, Iran, Italy, and Japan was issued on March 11, 2020 after India reported a sudden jump in confirmed cases (WHO n.d.). March 16, 2020 onwards all mass gatherings such as in schools, colleges, shopping complexes, and theatres were imposed to shut in the country. The countrywide three weeks lockdown imposed on 25$^{th}$ March, 2020, had shown a considerable reduction in the projected spread of COVID-19 in India. Almost all the countries imposed lockdowns to reduce the spread of COVID-19. A study evaluated the effects of lockdown in Spain and Italy. After the first lockdown, a considerable reduction in cases was observed in both the countries (Tobías 2020). They also suggested a timely intimation to the governments and health authorities to prevent the overburden on healthcare services.

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*Manuscript No. 1582*
*Received : 16 August, 2022; Accepted : 5 November, 2022*

### Transmission of COVID-19 through Water

Scarce information is available on the transmission of COVID-19 through water. Looking at the history of Coronaviruses many evidences had been found regarding the spread of 2003 SARS-CoV through water. The traces in water-bodies such as in tap water, hospital waste, sewage water, etc.have been reported. A case study that everyone had taken as reference was the Amoy Garden building case during 2003 SARS-CoV. There a spread among 329 residents of the residential estate in Hong Kong due to faulty building sewage was reported (Poon et al. 2004; Watts 2003; Yu et al. 2004). This case had increased the number of cases drastically in Hong Kong at the starting of Phase-2 of the outbreak as shown in Fig. 1.

Laboratory investigation reported the presence of a virus in the stool of patients which would have been discharged to the sewage line. The water vapors generated during floor drying, shower, and toilet-flush provided a route for the transmission of the virus among the other residents of the building. Some other viruses are generally detected in water which led to a considerable number of waterborne diseases such as gastrointestinal illness, viral hepatitis, conjunctivitis, polio etc. (Hamza and Bibby 2019; Haramoto et al. 2018; Rosa et al. 2020; Sabbahi and Ben 2017). Taking the case of Amoy Garden and the history of viruses as reference predictions of spreading SARS-CoV-2 by water have been made by researchers (Holshue et al. 2020; Ong et al. 2020; Xiao et al. 2020; Yeo, Kaushal, and Yeo 2020). A study (D'Amico et al. 2020) revealed about the diarrhea symptoms in SARS-CoV-2 patients. Thus the feces to oral transmission could be possible as it was hypothesized in the Amoy Garden case. Some recent literature from different parts of the world have reported water samples positive for COVID-19 (Medema et al. 2020; Jie Wang et al. 2020; Wu, Xu, and Xiao 2020). Some

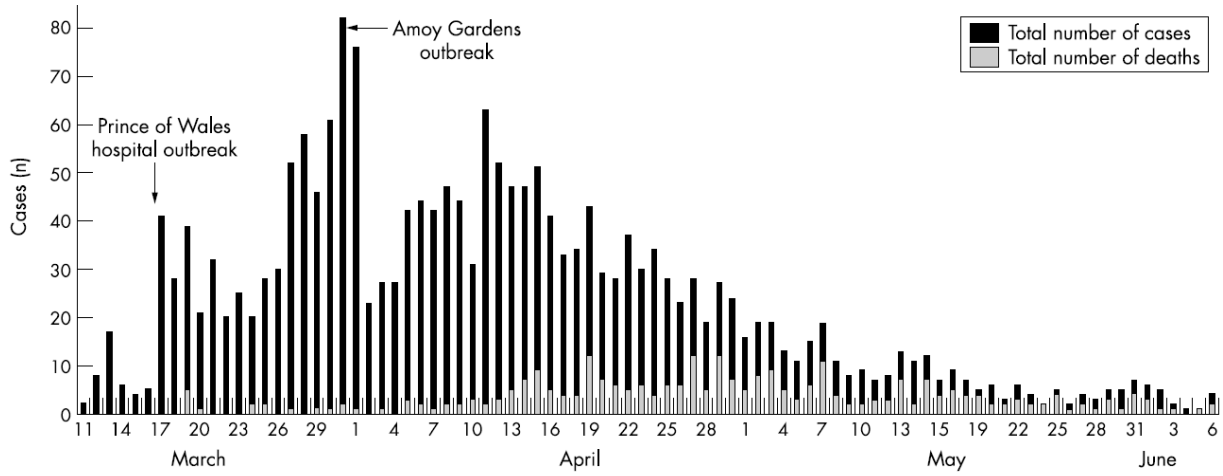


**Fig. 1 The three phases of the 2003 SARS-CoV outbreak in Hong Kong, China(Lee 2003).**

reported the traces up to 1000 genomic copies/liter and with 75-100% probability(Carducci et al. 2020). If such apprehensions and predictions prove true it could be very dangerous and difficult to control (Jiao Wang et al. 2020; Zhang et al. 2020). A testing in Brisbane, Australia by Ahmed et al. (Ahmed et al. 2020) detected two positive hits of SARS-CoV-2 in untreated water samples of a wastewater treatment plant in a densely populated area. Using Monte Carlo simulation a prediction of 171 to 1090 infected persons in those catchments was made. The numbers were found in reasonable agreement with the cases reported thereafter. As a preventive measure, various governments have imposed lockdowns in their respective countries to reduce the increasing number of cases. Thus a recommendation to stick to the water sampling and testing in densely populated areas was given by the researcher.

To the best of the author's knowledge, no study has been done which considers thecoming danger due to the approaching monsoon rains in India and neighboring countries. In this article, a review of the effect of meteorological parameters has been done. The effects of monsoon floods have been reviewed keeping in mind the damages and diseases caused during floods in past.An RBG model study using ImageJ software was done to check the geographical effect of population density and rainfall received in March to August, 2020 in different states of India, In the end, a suggestion to adhere to sanitization, disaster management, social-distancing, and lockdown is given to reduce the potential spread of COVID-19 in flood-prone regions.

## EFFECT OF METEOROLOGICAL PARAMETERS ON COVID-19

Various studies have revealed the dependence of COVID-19 spread on the weather conditions. A study in China associated a correlation between the COVID-19 cases and ambient temperature and found a positive correlation between the two below 2˚C (Xie and Zhu 2020). A study of pandemic in New York, USA (Bashir et al. 2020) found a correlation between the local climatic parameters such as temperature, humidity, rainfall, air quality, and wind speed with COVID-19 outspread. The study concluded average temperature, minimum temperature, and air quality as significant ones. Another similar study in Turkey (Şahin 2020) established the correlation between the COVID-19 cases and local climatic parameters throughout the incubation period of 14 days of SARS-CoV-2. The temperature of the same day, wind speed on 14 days ago, and the population were found more significant parameters. In Jakarta, Indonesia (Tosepu et al. 2020) found average temperature the most significant parameter in correlation with the number of cases. In Brazil (Prata, Rodrigues, and Bermejo 2020) similar results with a negative correlation between temperature and number of cases were observed. A threshold value of 25.8˚C was reported by a robust mathematical model. A detailed study in Iran (Ahmadi et al. 2020) included intra-provincial movement, solar radiation, and previously infected people in addition to the parameters considered by(Bashir et al. 2020). Partial correlation coefficient method was used to establish the correlation. The analysis shows that population and intra-provincial movements have a direct relationship with the infection rate. The areas with low solar radiation and low humidity are more prone to the outbreak. They also concluded that the COVID-19 outbreak is created due to sunspot phenomenon and predicted such type of pandemics at approximately 10 years of interval. (Jahangiri, Jahangiri, and Najafgholipour 2020) Another study in Iran estimated the sensitivity and specificity of ambient temperature and population on the rate of increase of COVID-19 spread. Population was concluded more sensitive and strict inspection and preventive actions were suggested for densely populated areas of the country.

(Coccia 2020) added one more important parameter in addition to other environmental parameters to the estimation of infection correlations. The emphasis on air pollution to human transmission of COVID-19 was given. The author took the reference of high infection rate and mortality

percentage in Italy as a reference for the study. The most polluted cities in Italy were reported with the maximum number of cases. The reason behind that was majorly assumed to be the high concentration of bio-aerosols and volatile organic compounds (VOCs). The facts were also supported by the proof that the mortalities caused were majorly among the elderly with a history of other respiratory diseases due to high pollution. Another supporting fact found was the presence of particulate matters (PM) which affects the immunity of children and the elderly. (Ma et al. 2020) investigated the effect of temperature, its diurnal range, and humidity on the deaths due to COVID-19 in Wuhan, China. The study concluded that the diurnal temperature range showed a positive relationship with the deaths, humidity showed the negative, and a thermally stable and comfortable environment was suggested for the patients in quarantine facilities and hospitals. (Cássaro and Pires 2020) concluded that the mathematical methods couldn't predict the number of COVID-19 cases during initial stages i.e. first 2-3 weeks. The causes of variability of prediction were identified as spread dynamics, population density, individual protection methods, and local meteorological factors etc.

The correlations discussed above may be subjected to many limitations due to area specificity and lack of transparency in the data. Thus the meteorological parameters which effect the COVID-19 spread include average temperature, diurnal temperature range, relative humidity, rainfall, air pollution, aerosols, population density, intra-provincial movement, and solar radiation. Among all these the parameters which showed positive correlation and may increase the outspread of COVID-19 are diurnal temperature range, rainfall, aerosols, population density, and intra-provincial movements. The parameters which showed negative correlation and may decrease the outspread of COVID-19 are average temperature, relative humidity, and solar radiation. Thus to find a correlation between COVID-19 spread and Monsoons which are multivariable and unpredictable in the long term will be difficult. Initially a hypothesiscan be made taking the references from past incidents of monsoons and facts related to SARS-CoV-2.

## MONSOON RAIN AND COVID-19

During the monsoon season from June to September the South Asian countries receive maximum precipitation bringing over 100 cm of rain in the areas. It is a boon for the farmers and is a major source of groundwater recharge (Kulkarni et al. 2018). But due to global warming weather extremities such as cyclones, cloudbursts, storms, dusty winds, increased extremities in temperature, increasing sea level have become very common these days(Ballesteros-Cánovas et al. 2020; Gupta 2020; Halgamuge and Nirmalathas 2017). This also has affected the precipitation patterns of monsoons. Increasing urbanization has resulted in excessive concretization of green lands, which has greatly affected the natural drainage system, and resilience of nature to adapt according to these changes in weather(Gusain et al. 2020). The occurrence of extreme rainfalls along with rapid urbanization, high population density, and aging sewage infrastructure, choked rivers lead to situations like floods in urban areas and river basins. Some studies in the past had predicted the increase in severity and frequency of floods (Attri and Tyagi 2010; Cao et al. 2013; Ramin and McMichael 2009). (Halgamuge and Nirmalathas 2017) confirmed these predictions by reporting 348 flood events, 121 in Australia, and 227 in India from 1985 to 2016. The reason behind which was increased water vapors in the environment due to global warming. It was concluded by (Vittal et al. 2016) after examining the data of the past 50 years for India. Areas close to coastal lines, river basins, and lakeshores were observed to be more prone to flash floods.

**Monsoon Floods**

Based on the above-mentioned facts some case studies of floods in India have been studied. Mumbai floods in 2005 which was caused by a cloudburst like situation which poured 94.5 cm in 14 hours over 30 $km^2$ area along with 4.48 m high tide(Bhagat, Guha, and Chattopadhyay 2006). Mumbai remained waterlogged for seven days. All the three major lakes of the city were overflowed, about 400 people and 20000 livestock lost their lives(Gupta 2020), and a huge loss of infrastructure also took place. Transportation, telecom, electricity, and other services were shut. The reason behind that was poor sanitization, huge population, slum, about 100 years old insufficient capacity drainage system, and inefficient early warning systems (Stecko and Barber 2007). The elevation of Mumbai is 14 m which is also in a range of the majority of flood spots in the country(Sansare and Mhaske 2020). In addition to Mumbai floods in 2005, many other cities had severe flooding such as Hyderabad in 2000, Ahmedabad in 2001, Delhi in 2002, 2003 and 2009, Chennai in 2004, Mumbai in 2005, Surat in 2006, Kolkata in 2007, Jamshedpur in 2008, and Guwahati and Delhi in 2010, Srinagar in 2014, Guwahati in 2014, Chennai in 2015, Hyderabad in 2016 and Ahmedabad in 2017, and the most recent in Kerala in 2018. The states along the coastal lines also faced the problems of flood due to sea level rise. A study by (Gupta 2020) had noticed frequency of rain exceeding 50 mm, and 100 mm during a day in all states and noticed various rain extremities in the country. Some neighboring countries also faced flood incidents in past such as Pakistan in 2010 and 2014 (Ballesteros-Cánovas et al. 2020; Baqir et al. 2012), Dhaka in 1988, 1998, and 2004 (Schwartz et al. 2006). Other than floods water-logging is very much common in different parts of South Asia during monsoons (Bhagat et al. 2006; Sansare and Mhaske 2020).

**Problems caused by floods**

Dramatic disturbances such as terrorism, disasters, and pandemics create setbacks to society, environment, and economy (Pascapurnama et al. 2018). Compared to other disasters floods cause more burdens on the economy because they last for as long as days, weeks, and even more (George 2011). Floods impact humans either directly with

coming in contact with water or indirectly with damage caused to the community infrastructure.

**The direct effects which flood situation can cause are as follows:**

- The drowning problem is most prominent during floods. This happens mainly in the areas prone to flash floods, or in Tsunami like situation in coastal areas(Chandramohan et al. 2017). Most deaths are attributed to the drowning of motor vehicles on submerged roads (French and Ing 1982). Drowning also happens to people when they are swept away from their house, try to cross a bridge, during evacuation, or during rafting in aggressive rivers and storm-water drains.
- The injuries due to building collapses, flowing debris in the water, or during maintenance of their houses after floods, and storm(Brewer, Morris, and Cole 1994; Schnitzler et al. 2007).
- Direct injuries and deaths caused by electrical lines, explosions in gas or oil pipelines, hypothermia, lightning strikes, etc. (George 2011).
- Disruption of health, transportation, and telecom services (Stecko and Barber 2007).

**The indirect effects which flood situation can cause are as follows:**

- The flood situation also affects the quality of water in the affected parts. The floodwater mixes with the food supply and water supply system and contaminate that with harmful disease-causing pathogens (Scoullos et al. 2020; Stecko and Barber 2007).
- Hazardous contamination due to runoff water from chemical factories, nuclear power plants, oil rigs, pesticides, and chemical fertilizers, etc. (George 2011; Kulkarni et al. 2018).
- Fecal contamination of agricultural land, irrigation water, streets, beaches, underground warehouses, etc. (Casteel, Sobsey, and Mueller 2006; D'Amico et al. 2020; Pianetti et al. 2004).
- Carbon Monoxide Poisoning due to release from the exhaust of generators, vehicles, thermal power plants, etc. (Daley, Shireley, and Gilmore 2001; Sniffen et al. 2005). which causes headaches, nausea, vomiting, etc. in the affected people (Fife et al. 2009).

**Disease outspreads during floods**

Floods cause a lot of disruption of services in the affected areas. Which causes the displacement of a lot of people to different places, temporary shelters, etc. (George 2011). Most of these places become overcrowded, poorly sanitized, and with limited food and health supplies (Pascapurnama et al. 2018). Such conditions may cause the outbreak of various water-borne, air-borne, and vector-borne (by mosquitoes) communicable diseases (Baqir et al. 2012; George 2011; Pascapurnama et al. 2018; Schwartz et al. 2006). The most common disease caused by floods is gastrointestinal infections due to *Shigella bacteria* which causes serious *diarrhea* and the disease can spread from human to human, or fecal to the human route [56]. (Liu et al. 2017) projected the future cases of similar bacterial disease and results were alarming. Some other harmful diseases which may spread during flood-like situation include *measles, malaria, tetanus, gas gangrene, hepatitis, typhoid*, etc. Floods also cause the outbreak of some viral diseases such as *pneumonia, rotavirus, norovirus, enterovirus, conjunctivitis*, etc (Pascapurnama et al. 2018; Scoullos et al. 2020). Flood also causes some *Acute Respiratory Infections (ARIs)* which may result in abnormal breathing and may transfer by any route among the survivors of floods (Pascapurnama et al. 2018). Pakistan floods in 2010 reported infectious diseases in the respiratory tract and caused deaths in the survivors. Bangladesh floods in 1988 reported ARI cases in about 17.4% of total ill cases and 13% of all the deaths. About 113981 cases of pneumonia, viral flu, bronchitis, and chronic obstructive pulmonary airway disease were reported (Baqir et al. 2012).

**RBG Model for COVID-19 Spread Analysis**

The rainfall data for March to August, 2020 was collected from the Indian Meteorological Department website (Monthly Average Rainfall n.d.). The COVID-19 data was collected from the COVID-19 resource center (COVID-19 Resource Center n.d.). The population density classification was referred from the census of India website (Census of India n.d.). The states with above average monthly average rainfall were highlighted with green color in the map as per the data available for the six months during the pandemic. The most affected states due to COVID-19 were highlighted using the red color on the map. The states with high population density were highlighted using the blue color on the map. The three images were processed using the ImageJ software. The three images were overlayed using the color merging channel function in ImageJ. The RBG model makes different combinations of colors after combining the three basic colours which is shown in the Fig. 2.

The four states namely Rajasthan, Uttar Pradesh, West Bengal, and Madhya Pradesh are depicted by white color for all the overlays thus both the population and rainfall could be the cumulative reasons for the spread of COVID-19. In the case of Maharashtra and Delhi, the population density is the dominating factor as in May these areas did not receive excess rainfall but the number of cases increased drastically. The eastern states of India reported very few COVID-19 cases which are due to low population density and low rainfall received during the early stages of the outbreak. But during the month of June to August the number of cases increase in these areas which is due to the rainfall during the monsoon period. The green color depiction of Haryana, Odisha, Himachal Pradesh, Uttrakhand, Chhatisgarh, and Jharkhand shows that these states received excess rainfall during the starting three months but due to low population density lower COVID-19 cases were reported there. But the cases rise in Haryana during the monsoon period. Gujrat and Punjab despite

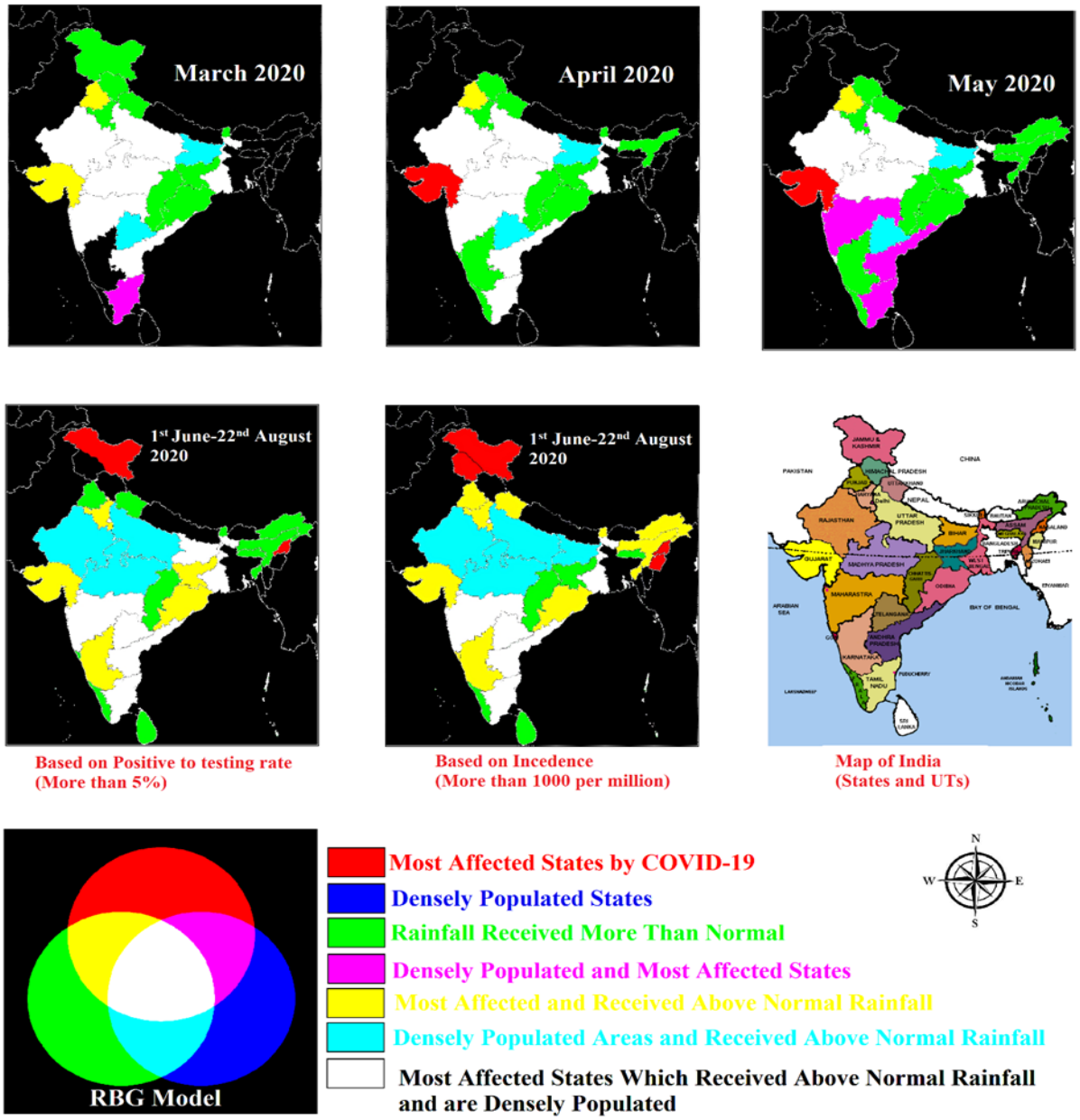


**Fig. 2 : RBG model analysis showing the effect of population density and rainfall on COVID-19 spread**

having low population density showed more cases because of excess rainfall during the early stages of the outbreak. Tamil Nadu, Andhra Pradesh being densely populated showed more cases and they also received excess rainfall in April month. The coastal areas especially the eastern coast reported more cases as already predicted due to the frequent weather extremities. More cases were reported in the southern states as the monsoon progressed from its onset since the month of June.

**Discussion and Conclusions**

The motivation for this study was the lack of awareness about the spread of COVID-19 by water. To the best of the author's knowledge, no study has been done by considering the dangerous situation which may be created due to the approaching monsoon rains in India and neighboring countries. To study the potential effect of monsoon on COVID-19 situation this study has been done. A literature review has been done on the potential transmission of SARS-CoV-2 through water.The effect of various meteorological parameters have been studied by doing an extensive literature review. Among all these the parameters which may increase the outspread of COVID-19 are diurnal temperature range, rainfall, aerosols, population density, and intra-provincial movements. The parameters which may decrease the outspread of COVID-19 are average temperature, relative humidity, and solar radiation. Thus to find a correlation between COVID-19 spread and Monsoons

in the long term will be difficult. Thus a hypothesiscan be made taking the references from past incidents of monsoons and facts related to SARS-CoV-2.

Monsoon rains are famous for frequent and long pouring hours, deluges, increased humidity, a decrease in temperature, and high winds. If we take aside the case of increased humidity all other factors are assumed to be favorable to the spread of COVID-19. The feces to oral transmission route may cause the fast transmission of COVID-19 in the places which had a history of water deluges and floods. The heavy rain and waterlogging also affects the transportation, telecom, and electricity distribution mechanism. Which may prevent the medical attention to the patients, slow down the rapid testing, and the handling of PPE suits may become difficult due to high winds and pouring water. After collecting the facts about SARS-CoV-2 and studying its stats for India it is clear that the COVID-19 cases are still increasing in the country and most affected parts are the coastal areas of the country. These parts generally face the problems of choked sewage lines due to combined high tides and monsoon rains. Such incidents resulted in numerous incidents of poor sanitization situations in slum areas. So there is a huge concern about the spread of COVID-19 in such kind of situations. Thus the disaster management teams and governments of countries must keep in mind the approaching monsoon while planning mitigation actions against COVID-19 spread.

## ABBREVIATIONS

| | |
|---|---|
| COVID-19 | Coronavirus Disease |
| CoV | Coronavirus |
| WHO | World Health Organization |
| SARS | Severe Acute Respiratory Syndrome |
| MERS | Middle East Respiratory Syndrome |

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