This manuscript is a non-peer-reviewed preprint and is currently under peer review in a journal.

COVID-19 Pandemic – Possible implications and effects of monsoons in the Indian sub-continent.

Renjith VishnuRadhan[1*], Eldho T I[1], Ankita Misra[2], Jayakrishnan P R[3], Zaki Zainudin[4]

[1]Department of Civil Engineering, Indian Institute of Technology Bombay, Powai, Mumbai, Maharashtra 400076, India,

[2]Institute of Oceanography and Environment, Universiti Malaysia Terengganu (UMT), Kuala Nerus, Terengganu 21030, Malaysia

[3]Academy of Climate Change Education and Research, Kerala Agricultural University, Vellanikkara, Thrissur, Kerala 680656, India.

[4]Independent water quality and modeling specialist, Klang, Selangor, Malaysia

Abstract

The world is facing an unprecedented time owing to the ongoing COVID 19 pandemic. The research community is racing to find a solution to contain the outbreak, leading to the proposals of many possible routes of the virus transmission and its dynamics. The Indian sub-continent is about to experience the monsoon season, which often leads to heavy rainfall and flooding in the region, affecting the urban areas the most. In this communication, we list out the possible outcomes of the synergistic interaction between the ongoing pandemic and the monsoon season in urban regions and megacities. Some of the risk factors emanating from the interaction are the impacts on seasonal monsoon-related disease transmission, sewerage effluents, and potable water sources. We also discuss some socio-economic aspects of the implications of monsoon during the pandemic time, such as transport disruptions and increased pressure on the accessibility to the health care systems. We hope that the communication shall bring forth stimulating discussion and detailed investigations regarding the dimensions of monsoon impact. In addition to this, the observations shall aid the policymakers and governance systems in charting out the best fit mitigation and adaptation strategies to tackle the perils of COVID-19 during the monsoon season.

Keywords: COVID-19; SARS-CoV-2; monsoon; urban; Indian sub-continent; water

*Corresponding author: Renjith VishnuRadhan, renjithvr@iitb.ac.in, renjitvishnu@gmail.com

Ph No: +91 9011978574

1. Introduction

The coronavirus disease 2019 (COVID-19) (WHO, 2020) is a rapidly spreading novel respiratory infection caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) (Gorbalenya et al. 2020). Person-to-person transmission is a common route for spreading the infection via direct contact or through droplets spread by coughing or sneezing by an infected individual (Rothan et al. 2020). Various other transmission routes have been proposed since the diagnosis of the novel virus for the first time in China; including airborne transmission (Morawska and Cao 2020), dual ocular route (Napoli et al. 2020), faecal–oral route (Hindson 2020), eye to nose route (Qing et al. 2020), perinatal transmission (Alzamora et al. 2020), transmission due to environmental factors (Qu et al. 2020) and venereal transmission (Patri et al. 2020).

Countries in the South Asian region are battling the pandemic when the monsoon season is about to commence, around early June. The period June–December, when the Indian sub-continent is under the influence of the monsoon, is divided into two seasons, the southwest (summer) monsoon from June to September and the northeast monsoon from October to December. The Indian subcontinent receives over 75% of the mean annual rainfall during the summer monsoon season (June–September), with July and August being the peak monsoon months (Kumar et al. 2009). The monsoon season incurs extreme seasonal flooding in the South Asian regions, primarily affecting the densely populated urban areas; some recent examples are 2015Chennai floods, 2017 Mumbai flood, 2017 Dhaka flood, 2018 Kerala floods. 2018 Lahore flood, 2019 Kerala floods.

In this communication, the possible implications and effects of monsoon on the ongoing COVID-19 crisis in the monsoon-influenced regions, where urban agglomerations are prominent, are

discussed. We hope that this discussion will instigate further stimulating and detailed investigations and discussions.

2. Monsoon and COVID-19 transmission: The odds-on

The monsoon season is a season of elevated levels of vector-borne and water-borne diseases, such as dengue, malaria, cholera, influenza, hepatitis, typhoid, and gastroenteritis which are the more common diseases, among others (Khan et al. 2011; Dhara et al. 2013). The rainfall during the period has profound effects on the epidemiology of these diseases. Previous experiences show that these infectious diseases pose severe problems of various dimensions for the nations in the Indian sub-continent region, and their population is at a higher risk of being exposed to multiple viruses, bacteria, and other infections during the monsoon period than the other seasons. For example, respiratory viral infections were found mainly during the rainy seasons in Asian, African, and South American countries (Shek and Lee 2003), and epidemiological data show that there is a relationship between influenza virus infection and rainfall (Pica and Bouvier 2012). Temperature and humidity are also among the critical controlling factors that impact the spatial-temporal incidence and transmission of several of these infectious diseases during the monsoon period.

A recent study (Sobral et al. 2020) observed a positive correlation between precipitation and SARS-CoV-2 transmission, with countries having higher rainfall measurements showing an increase in disease transmission. But, the comprehensive nature of the virulence factors associated with COVID-19 during a prolonged rainy season remains unknown as of now. There is a prevailing strong wind regime during the monsoon season, and recent pieces of evidence show that wind speed is positively correlated with COVID-19 cases in some regions (Bashir et al. 2020; Sahin,

2020). While wind speed alone may not explain much of the variance in the confirmed positive case counts, but combined with temperature, wind speed, and relative humidity, it could best predict the epidemic situation (Chen et al. 2020). Monsoon season is a period when there are different combinations of meteorological influences available across the Indian subcontinent, and it will be worth exploring and evaluating the best-fit epidemic scenarios. It is also unknown whether COVID-19 increases the susceptibility towards other monsoon induced infectious diseases or- vice-versa. Co-infections are potentially lethal in COVID-19 patients and are a highly unexplored realm (Cox et al. 2020). A recent study (Kim et al., 2020) from Northern California reports co-infection between SARS-CoV-2 and other respiratory pathogens, indicating that co-infections can happen when there is a surge in various diseases during the monsoon.

Monsoon period is also known for the voracious seasonal flooding, causing the flood impacts that are much exacerbated in the urban agglomerations due to various socio-economic factors (Dhiman et al. 2019), which are endogenous to urban areas. We have considered three countries (Bangladesh, India, and Pakistan) in the Indian sub-continent region because these are the most populous and sites of major megacities, in addition to having the highest number of positive COVID-19 cases in the region. Figure 1 shows the monsoon rainfall and major cities in the Indian sub-continent. Megacities across this region (for example, Chennai, Delhi, Dhaka, Karachi, Kolkata, Lahore, Mumbai), where severe seasonal monsoon flooding occurs, are currently the epicenters of disease transmission. These urban agglomerations have insufficient sewage and drainage infrastructures, the capacity of which are often overwhelmed during the monsoons. Further, untreated sewage effluents are the dominant class of pollutants in the urban regions of South Asian regions (Raju 2019), and seasonal flooding often paves the way for contamination of urban water bodies and municipal water sources by the effluents. When

narrowing down to the type of contamination in the region during the monsoon induced flooding, faecal contamination is a prominent aspect (Sirajul Islam et al. 2007; Subbaraman et al. 2013; Nabeela et al. 2014), rendering the population susceptible towards infectious outbreaks. Figure 2 shows the number of confirmed COVID-19 (as of May 25) cases in the Indian sub-continent countries where the megacities have a substantial contribution to the confirmed positive cases. Other countries (Bhutan, Maldives, Nepal, and Sri Lanka) in the sub-continent region have relatively less positive cases compared to these three countries.

SARS-CoV-2 RNA has been detected in sewage effluents (Ahmed et al., 2020; La Rosa et al., 2020; Randazzo et al. 2020) and there are emerging indications that the viral RNA is present in faeces (Wu et al. 2020) and urine (Kashi et al. 2020) of infected individuals. Considering the lacunae in the functioning of sewerage infrastructure and issues in effluent management in the South Asian cities, it is highly likely that the effluents contain traces of viral RNA. There is a possibility that this can ultimately reach the water bodies and eventually potable water sources; this pathway can be exacerbated during the monsoon flooding. Coronaviruses can remain viable in sewage for up to 14 days depending on the environmental conditions such as temperature, and their association with biofilms (Quilliam et al. 2020) and for more extended periods in the drinking water (Naddeo and Liu, 2020). However, their persistence is lower when compared with non-enveloped viruses (Annalaura et al. 2020). There are substantial pieces of evidence of the spread of severe acute respiratory syndrome (SARS), caused by a similar virus as SARS-COV2, in Hong Kong in 2003 by "faecal droplet" route via sewage and drainage systems (WHO, 2003). There is a possibility of a faecal transmission route due to the monsoon induced water problems in major cities in the Indian sub-continent. Though the infectivity and the survival of the viral RNA in the effluents are not confirmed explicitly yet, the infection transmission dynamics during the expected

seasonal flooding associated with the monsoon season may pose new challenges. Even if the water-borne route of the COVID-19 infection is not yet established, researchers, policymakers, and governance systems must think ahead and deploy the appropriate pre-emptive investigations to inform countermeasures rapidly (VishnuRadhan et al. 2020).

Personal Protective Equipments (PPEs), made of plastics, are saving millions of lives during the pandemic (Czigány and Ronkay 2020). Also, single-use plastic materials are widely utilized in the forefront of COVID-19 responses. But, the management of the disposed of equipments is an immense challenge for cities that are already facing waste management challenges. The quantum of plastic waste generated as a result of the pandemic is massive, especially in cities having a huge population. Leakage of large plastic litter (macroplastics) into the ocean is a major environmental problem, a significant fraction of this originates from coastal cities during extreme rainfall events (Axelsson and van Sebille 2017; VishnuRadhan et al. 2019). This is equally true for other water bodies such as ponds, lakes, and rivers. Also, there have been many instances of enhanced flooding due to the clogging of the drainage systems by plastics (Pahl et al. 2017; Lewis et al. 2018) during heavy rainfall. The emerging question in the wake of COVID-19 pandemic is not whether plastic is a polluter or a protector, but how well the plastic usage and disposal can be managed in a sustainable and environmentally friendly way.

3. Socio-economic impacts of monsoon-COVID-19 synergy: The adds-on

The monsoon associated flooding usually incurs substantial economic losses and imparts heavy burden on the local, regional, and national administrative units in the Indian sub-continent region. For example, the estimates of the total losses from the July 2005 flood (26–27 July) in Mumbai range from US$ 1.1 to 5 billion, excluding large informal sectors comprising households and small

commercial establishments (Patankar and Patwardhan 2016). Other cities in the sub-continent also experience similar flood induced economic losses due to the economic–social disorientation and associated shutdown. This can ultimately affect the prevailing socio-economic dynamics of the respective countries as these cities are their financial and commercial centers. The COVID-19 induced economic ripple has started appearing around the world and, emerging economies are currently affected due to collapsing exports, dwindling remittances, and tightening international credit conditions (Hevia and Neumeyer 2020). The South Asian regions host major emerging economies and global markets, and the combined impact of monsoon flood induced losses, and those by the ongoing pandemic will be overwhelming to the prevailing economic situations.

There is another easily-overlooked and possible threat associated with the monsoon induced flooding. Transport disruptions are widespread in the cities during heavy rains and flooding. These disruptions can potentially impede the accessibility to healthcare facilities by the suspected patients, which can aggravate their health condition as the timing of health care access is a critical factor in managing and successfully surviving COVID-19. The COVID-19 patients, as well as individuals suspected of having the infection, need continuous interactions with a spectrum of health care facilities, including screening, detection, and post-diagnosis treatments. With the restriction of movement imposed by the heavy rains and flooding, the access and interaction with the health care system can be nearly impossible. The rapid movement of supplies, both the essential and medical, to the outbreak nodes and quarantine centers in the cities, can also get affected. Currently, we do not know the resilience, in the wake of COVID-19 pandemic, of health care infrastructure and associated facilities in the South Asian cities to extreme weather conditions such as monsoon flooding. We know one thing for sure, this monsoon comes with a lot of challenges and opportunities.

Traditionally vulnerable socio-economic classes in the cities have higher risks of exposure towards various perils of the dynamic interaction between the ongoing pandemic and the upcoming monsoon season, which may pose multiple justice questions also. For example, squatter settlements are currently the epicenters of the COVID-19 in Mumbai. Similar conditions also prevail in other megacities having a substantial squatter population. As the virus continues to spread across the world, it brings with it multiple new stresses such physical and psychological health risks, isolation and loneliness, domestic violence, and job losses (Bradbury-Jones and Isham 2020). The monsoon influence can exacerbate these stresses in densely populated urban area, increasing the risk factors for the already vulnerable population who are the overlooked victims of the ongoing pandemic. The effective strategies recommended to control the spread of the infection, social distancing and frequent hand washing, are not easy for the millions of people who live in highly dense communities with insecure housing, and poor sanitation and access to clean water (The Lancet 2020). In case of a flood induced by heavy rainfall in densely populated areas, people displaced by the flooding shall be immediately shifted to relief camps for rehabilitation. There are evident shortcomings in social distancing norms in densely populated areas and can be flouted even more without adequate precautions in relief camps. The restricted availability of clean water during these periods can also impede the recommended hand washing regime. Considering all these facts, we can ascertain that the upcoming monsoon season will be a period of challenges and opportunities of diverse manners.

4. Conclusions

Monsoon has shaped history (Gupta et al. 2019) and survival (Gadgil and Kumar 2006) of the inhabitants of the Indian sub-continent. The upcoming monsoon season during the turbulent times of the COVID-19 pandemic offers various challenges and possibilities in the region. The potential vulnerabilities of the urban areas and their societies due to the synergistic interaction of the pandemic and the monsoon season expose them to multiple risk factors. It is challenging to isolate the relative contribution of these factors toward the city dynamics during the pandemic time. Still, the urban resilience towards any unforeseen event can be enhanced through proper planning and management. Governance systems should divert major attention towards various bottleneck problems during the monsoon season, such as seasonal monsoon-related disease transmission, sewerage infrastructure and effluent management, contamination of potable water sources, and transport disruptions and access to the health care system. Timely interventions of governance systems, as well as citizens, can reduce the likelihood of exposures to risk factors, to some extent, and thus prevent another possible wave of disease outbreak with a much higher morbidity rate than the present. Potential avenues encompassing multi-faceted ways of the response of urban agglomeration to interactions and repercussions of the COVID-19 outbreak and a long rainy season will provide opportunities to understand and tackle future pandemics as well. An area of possible exploration and utilization is geospatial technologies, which can enhance the efficiency of urban management in the pandemic time. We hope that this communication can aid researchers, governance systems, and policymakers in charting out mitigation and adaptation strategies specifically for monsoon-influenced urban areas, as the virus is expected to persist (WHO 2020) even after the lifting of the ongoing global lockdown. The concept of living with the flood (Liao

et al. 2008) has been successful in many flood-affected regions around the world. Similarly, it is the need of the hour that communities should start practicing the concept of living with the virus, at least until the development of a vaccine or a medication to prevent the transmission of the infectious virus successfully.

Acknowledgments

Renjith VishnuRadhan acknowledges an Institute Post-Doctoral fellowship from IIT Bombay. Ankita Misra acknowledges an Institute Post-Doctoral fellowship from Institute of Oceanography and Environment, Universiti Malaysia Terengganu (UMT). Some model figures used in the graphical abstract are modified and obtained from www.freepik.com. The figure in the graphical abstract showing the predicted advance of the southwest monsoon is obtained from https://mausam.imd.gov.in/imd_latest/contents/monsoon.php.

References

Ahmed, W., Angel, N., Edson, J., Bibby, K., Bivins, A., O'Brien, J. W., ... & Tscharke, B. (2020). First confirmed detection of SARS-CoV-2 in untreated wastewater in Australia: A proof of concept for the wastewater surveillance of COVID-19 in the community. *Science of The Total Environment*, 728, 138764.

Axelsson, C., & van Sebille, E. (2017). Prevention through policy: Urban macroplastic leakages to the marine environment during extreme rainfall events. *Marine pollution bulletin*, *124*(1), 211-227.

Alzamora, M. C., Paredes, T., Caceres, D., Webb, C. M., Valdez, L. M., & La Rosa, M. (2020). Severe COVID-19 during pregnancy and possible vertical transmission. *American Journal of Perinatology*, 18, 18.

Annalaura, C., Ileana, F., Dasheng, L., & Marco, V. (2020). Making waves: Coronavirus detection, presence and persistence in the water environment: State of the art and knowledge needs for public health. *Water Research*, 179, 115907.

Bradbury-Jones, C., & Isham, L. (2020). The pandemic paradox: the consequences of COVID-19 on domestic violence. *Journal of clinical nursing*, https://doi.org/10.1111/jocn.15296.

Bashir, M. F., Ma, B., Komal, B., Bashir, M. A., Tan, D., & Bashir, M. (2020). Correlation between climate indicators and COVID-19 pandemic in New York, USA. *Science of The Total Environment*, 728, 138835.

Chen, B., Liang, H., Yuan, X., Hu, Y., Xu, M., Zhao, Y., ... & Zhu, X. (2020). Roles of meteorological conditions in COVID-19 transmission on a worldwide scale. *medRxiv*, doi: https://doi.org/10.1101/2020.03.16.20037168.

Cox, M. J., Loman, N., Bogaert, D., & O'grady, J. (2020). Co-infections: potentially lethal and unexplored in COVID-19. *The Lancet Microbe*, 1(1), E11.

Czigány, T., & Ronkay, F. (2020). The coronavirus and plastics. *eXPRESS Polymer Letters*, *14*(6), 510-511.

Dhara, V. R., Schramm, P. J., & Luber, G. (2013). Climate change & infectious diseases in India: Implications for health care providers. *The Indian journal of medical research*, *138*(6), 847.

Dhiman, R., VishnuRadhan, R., Eldho, T. I., & Inamdar, A. (2019). Flood risk and adaptation in Indian coastal cities: Recent scenarios. *Applied Water Science*, *9*(1), 5.

Gadgil, S., & Kumar, K. R. (2006). The Asian monsoon—agriculture and economy. In *The Asian Monsoon* (pp. 651-683). Springer, Berlin, Heidelberg.

Gorbalenya, A. G., Baker, S. C., & Baric, R. S (2020). The species Severe acute respiratory syndrome-related coronavirus: classifying 2019-nCoV and naming it SARS-CoV-2, *Nature Microbiology*, 5, 536–544.

Gupta, A. K., Dutt, S., Cheng, H., & Singh, R. K. (2019). Abrupt changes in Indian summer monsoon strength during the last~ 900 years and their linkages to socio-economic conditions in the Indian subcontinent. *Palaeogeography, Palaeoclimatology, Palaeoecology*, *536*, 109347.

Hevia, C., & Neumeyer, P. A. (2020). A perfect storm: COVID-19 in emerging economies. VoxEU CEPR Policy Portal. https://voxeu.org/article/perfect-stormcovid-19-emerging-economies. Accessed on 17 May.

Hindson, J. (2020). COVID-19: faecal–oral transmission?. *Nature Reviews Gastroenterology & Hepatology*, 17(5), 259-259.

Kashi, A. H., Fallah-karkan, M., Amini, E., & Vaezjalali, M. (2020). The Presence of COVID-19 in Urine: A Systematic Review and Meta-analysis of the Literature. medRxiv. doi: https://doi.org/10.1101/2020.05.15.20094920.

Khan, M. M. H., Krämer, A., & Prüfer-Krämer, L. (2011). Climate change and infectious diseases in megacities of the Indian subcontinent: a literature review. In *Health in megacities and urban areas* (pp. 135-152). Physica, Heidelberg.

Kim, D., Quinn, J., Pinsky, B., Shah, N. H., & Brown, I. (2020). Rates of co-infection between SARS-CoV-2 and other respiratory pathogens. The Journal of the American Medical Association, doi:10.1001/jama.2020.6266.

Kumar, M. R., Krishnan, R., Sankar, S., Unnikrishnan, A. S., & Pai, D. S. (2009). Increasing trend of "break-monsoon" conditions over India—role of ocean–atmosphere processes in the Indian Ocean. *IEEE Geoscience and Remote Sensing Letters*, 6(2), 332-336.

La Rosa, G., Iaconelli, M., Mancini, P., Ferraro, G. B., Veneri, C., Bonadonna, L., Lucentini, L., & Suffredini, E (2020). First detection of SARS-CoV-2 in untreated wastewaters in Italy. *Science of The Total Environment*, 736, 139652.

Lancet T. (2020). Redefining vulnerability in the era of COVID-19. *The Lancet*, 395, 1089.

Lewis, H., Retamal, M., & Atherton, A. (2018). Addressing plastic pollution in India, Background paper prepared for Mumbai July 2018 Business forum on Addressing Plastic Pollution in India, prepared for Stewart Investors, Institute for Sustainable Futures, University of Technology Sydney, Australia.

Liao, K. H. (2014). From flood control to flood adaptation: a case study on the Lower Green River Valley and the City of Kent in King County, Washington. *Natural hazards*, *71*(1), 723-750.

Morawska, L., & Cao, J. (2020). Airborne transmission of SARS-CoV-2: The world should face the reality. *Environment International*, 139, 105730.

Nabeela, F., Azizullah, A., Bibi, R., Uzma, S., Murad, W., Shakir, S. K., ... & Häder, D. P. (2014). Microbial contamination of drinking water in Pakistan—a review. *Environmental Science and Pollution Research*, 21(24), 13929-13942.

Naddeo, V., & Liu, H. (2020). Editorial Perspectives: 2019 novel coronavirus (SARS-CoV-2): what is its fate in urban water cycle and how can the water research community respond?. *Environmental Science: Water Research & Technology*, 6, 1213-1216.

Napoli, P. E., Nioi, M., d'Aloja, E., & Fossarello, M. (2020). The Ocular Surface and the Coronavirus Disease 2019: Does a Dual 'Ocular Route' Exist?. *Journal of Clinical Medicine*, 9(5), E1269.

Pahl, S., Wyles, K. J., & Thompson, R. C. (2017). Channelling passion for the ocean towards plastic pollution. *Nature human behaviour*, *1*(10), 697-699.

Patankar, A., & Patwardhan, A. (2016). Estimating the uninsured losses due to extreme weather events and implications for informal sector vulnerability: a case study of Mumbai, India. *Natural Hazards*, 80(1), 285-310.

Patrì, A., Gallo, L., Guarino, M., & Fabbrocini, G. (2020). Sexual transmission of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2): A new possible route of infection?. *Journal of the American Academy of Dermatology*, 82(6), e227.

Pica, N., & Bouvier, N. M. (2012). Environmental factors affecting the transmission of respiratory viruses. *Current opinion in virology*, 2(1), 90-95.

Qing, H., Li, Z., Yang, Z., Shi, M., Huang, Z., Song, J., & Song, Z. (2020). The possibility of COVID-19 transmission from eye to nose. *Acta ophthalmologica*, 98(3), e388-e388.

Qu, G., Li, X., Hu, L., & Jiang, G. (2020). An imperative need for research on the role of environmental factors in transmission of novel coronavirus (COVID-19). *Environmental science & technology*, 54(7), 3730–3732.

Quilliam, R. S., Weidmann, M., Moresco, V., Purshouse, H., O'Hara, Z., & Oliver, D. M. (2020). COVID-19: The environmental implications of shedding SARS-CoV-2 in human faeces. *Environment International*, 140, 105790.

Raju, A. S. (Ed.). (2019). Human Security in South Asia: Concept, Environment and Development. Taylor & Francis.

Randazzo, W., Truchado, P., Cuevas-Ferrando, E., Simón, P., Allende, A., & Sánchez, G. (2020). SARS-CoV-2 RNA in wastewater anticipated COVID-19 occurrence in a low prevalence area. *Water Research*, 181, 115942.

Rothan, H. A., & Byrareddy, S. N. (2020). The epidemiology and pathogenesis of coronavirus disease (COVID-19) outbreak. *Journal of autoimmunity*, 109, 102433.

Şahin, M. (2020). Impact of weather on COVID-19 pandemic in Turkey. *Science of The Total Environment*, 728, 138810.

Shek, L. P. C., & Lee, B. W. (2003). Epidemiology and seasonality of respiratory tract virus infections in the tropics. *Paediatric respiratory reviews*, 4(2), 105-111.

Sirajul Islam, M., Brooks, A., Kabir, M. S., Jahid, I. K., Shafiqul Islam, M., Goswami, D., ... & Luby, S. (2007). Faecal contamination of drinking water sources of Dhaka city during the 2004 flood in Bangladesh and use of disinfectants for water treatment. *Journal of applied microbiology*, 103(1), 80-87.

Sobral, M. F. F., Duarte, G. B., da Penha Sobral, A. I. G., Marinho, M. L. M., & de Souza Melo, A. (2020). Association between climate variables and global transmission oF SARS-CoV-2. *Science of The Total Environment*, 729, 138997.

Subbaraman, R., Shitole, S., Shitole, T., Sawant, K., O'brien, J., Bloom, D. E., & Patil-Deshmukh, A. (2013). The social ecology of water in a Mumbai slum: failures in water quality, quantity, and reliability. *BMC Public Health*, 13(1), 173.

VishnuRadhan, R., Divya David T, Eldho, T. I, Zaki Z, Casey K. C., & Jamal H. H., (2020). Baseline research timing in turbulent times. E-letter comment on 'Research opportunities in pandemic lockdown' in Science, Vol. 368, Issue 6491, pp. 594-595. https://science.sciencemag.org/content/368/6491/594/tab-e-letters, accessed on 24 May.

VishnuRadhan, R., Eldho, T. I., & David, T. D. (2019). Can plastics affect near surface layer ocean processes and climate?. Marine pollution bulletin, 140, 274-280.

WHO (2003). Inadequate plumbing systems likely contributed to SARS transmission. World Health Organization, https://www.who.int/mediacentre/news/releases/2003/pr70/en/. Accessed on 18 May.

WHO (2020). Naming the coronavirus disease (COVID-19) and the virus that causes it. World Health Organization (WHO), https://www.who.int/emergencies/diseases/novel-coronavirus-2019/technical-guidance/naming-the-coronavirus-disease-(covid-2019)-and-the-virus-that-causes-it. Accessed on 17 May.

Wu, Y., Guo, C., Tang, L., Hong, Z., Zhou, J., Dong, X., ... & Kuang, L. (2020). Prolonged presence of SARS-CoV-2 viral RNA in faecal samples. *The lancet Gastroenterology & hepatology*, 5(5), 434-435.

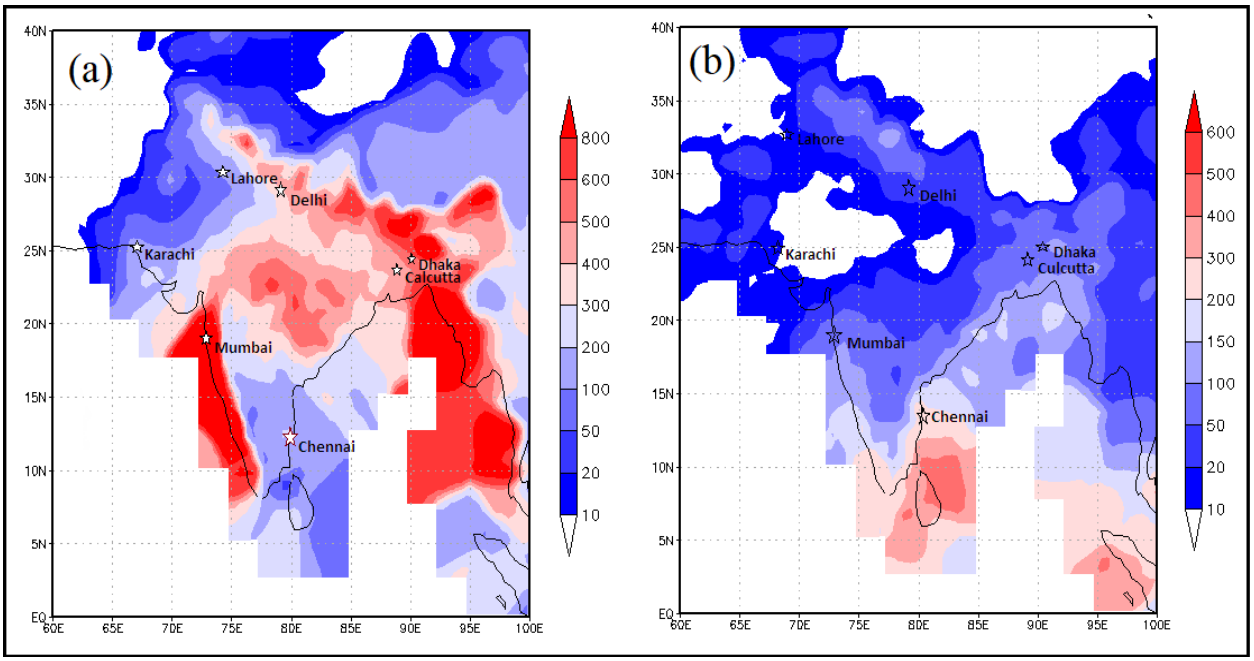

Figure 1: 2019 Monsoon rainfall and major cities in the Indian sub-continent coming under the monsoon influence, a) Accumulated rainfall (mm) for June- September (southwest monsoon) and b) Accumulated rainfall (mm) for October-December (northeast monsoon). Data source: http://apdrc.soest.hawaii.edu/las/v6/constrain?var=1776; CPC interpolated monthly rainfall.

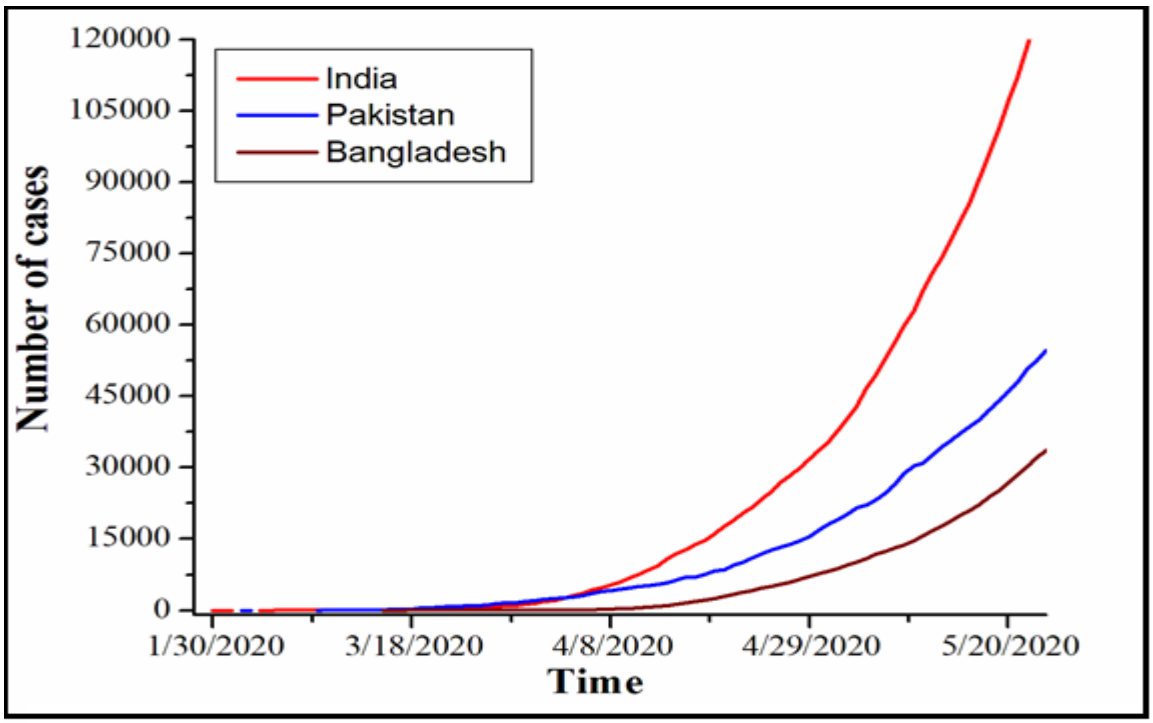

Figure 2: The number of confirmed COVID-19 (as of May 25) cases in India, Pakistan and Bangladesh. Data source: India - https://www.mohfw.gov.in/, Pakistan - https://www.nih.org.pk/, Bangladesh - https://www.iedcr.gov.bd/