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Mega festivals like MahaKumbh, a largest mass congregation, facilitated the transmission of SARS-CoV-2 to humans and endangered animals via contaminated water

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ABSTRACT

Our surrounding environment has been influenced by the COVID-19 pandemic situation. The second wave of COVID-19 in India has proven to be more devastating and aggressive than the first wave of the pandemic, which led to recognizing India as one of the world's topmost worst-hit nations considering >4000 fatalities reported in a single day in May 2021. Such "resurgence and acceleration" of COVID-19 transmission has been fuelled by the MahaKumbh festival and political mass gathering (elections rallies) events, where the COVID-19 protocols have been ignored by millions of pilgrims/followers. The present review discusses only the consequences of this year's MahaKumbh festivals, the largest religious mass gathering on earth, which was held during the COVID-19 pandemic in India, and its impact on both the spread of SARS-CoV-2 among participants and their families and its influence on the quality of the river Ganga. This article tries to give readers outside of India an overview of how much impact of any such single large gathering of any relgion in any part of the world can drive coronavirus infections and effectively commence the second/third wave outbreak with this case study. Furthermore, the religious large scale celebration are widely accepted through out the world that have played a significant role in the spread of the pandemic into remote villages and towns all over the subcontinent/world, thus affecting many areas with insufficient healthcare facilities that have been relatively spared. This review also highlights the potential risk of transmission from infected humans into the aquatic environment of the river Ganga. Besides the obvious relevance of SARS-CoV-2, a large variety of other water-related disease vectors (bacteria, viruses, and protozoa) stemming from visitors to the religious congregation were introduced into the upstream regions of the Ganga river. Their sheer number is assumed to have had a severe influence on its delicate ecosystem, including endangered mammals such as the river Dolphins. The detailed epidemiological and clinical study on transmission routes of SARS-CoV-2 is the need of the hour to understand the pathogenesis of RNA virus infection and prevent the massive spreading of such infectious respiratory diseases. An interdisciplinary approach, rooted in evidence-based efficient learning, contextual strategies, and a streamlined unified approach should be adopted to help in the development of a proactive prevention model during future MahaKumbh festival (and similar religious gatherings) instead of just "picking up the pieces" in a conventional post-event model.

The emergence of the severe acute respiratory syndrome coronavirus type 2 (SARS-CoV-2) and its associated COVID-19 disease in January 2019 lead to the outbreak of a global pandemic resulting in severe health concerns with nearly 197 million people affected (and >4.0 million deaths) in >200 countries around the globe by the 3rd August 2021 and posed environmental, economic, and social challenges (WHO, 2021). To impede the spread of infection, non-pharmaceutical precautions such as local lockdowns, social distancing, increased hand hygiene, and the use

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of personal protection equipment (PPE), such as facemasks, are being practiced and proved to be successful (Askitas et al., 2021). In India, an overall improving situation became grimmer in April 2021 due to the fatal outbreak of the second wave of COVID-19, which is reported to cause average daily deaths of more than 2,000 (Singh et al., 2021). The super spreading of the second wave of COVID-19 across the country has created a formidable challenge leading to the recognition of India (~11 million active cases) as one of the top five worst-hit nations after the USA (~24 million cases) as of 21st January 2021 (Ganguly and Chakraborty, 2021). COVID-19 transmission has been notably accelerated by several religious events (MahaKumbh festival) and political mass gatherings, where COVID-19 containment protocols at all times have been tossed away (The Lancet, 2021). The pivotal role of SARS-CoV-2 B.1.617 (or Delta) lineage and other variants of concern (e.g., B.1.1.7 or Alpha) along with the massive congregation of people have been identified as potential and likely contributing factors towards the rapid rising of the second wave of COVID-19 (Singh et al., 2021).

The MahaKumbh festival is considered the biggest religious human mass gathering on earth every 12 years. In 2021, more than 5 million devotees from different parts of India assembled for such a religious festival at Haridwar, an ancient Hindu pilgrimage city located at the river bank Ganga in the northern state of Uttarakhand (Quadri and Padala, 2021). It has been estimated that nearly 7 million pilgrims have converged (and flouted COVID-19 norms) at Har Ki Pauri ghat in Haridwar for the holy bath in the Ganga from January 14 to April 30, 2021. As of April 12, 2021, around 0.2 million saffron-clad seers and ash-smeared Nagas have contributed to the rapidly moving upward trajectory of COVID-19 cases (>35,000 in one week period) (Oestigaard, 2021). As expected, the upsurge of COVID-19 during the gigantic event of mass bathing resulted in the potential "super-spreading" of aerosols and airborne SARS-CoV-2 virions among the mass of devotees and seers (Fig. 1). The likelihood of rapid virus dispersal throughout the crowd and subsequently (upon their return to villages and cities all over the Indian subcontinent) the country was very high. Amidst the ongoing MahaKumbh festival in April, an increase of nearly 89-fold in COVID-19 cases has been documented in Uttarakhand compared to February (the initial period of the festival) (Upadhyay, 2021), with scores of transmissions that have not been picked up by clinical diagnostics (Inbaraj et al., 2021). The number of confirmed positive cases that have been found among MahaKumbh returnees across the country (~0.4 million cases on May 8, 2021, a global record), clearly indicates to what immense extend congregated religious gathering has fuelled India's coronavirus outbreak and led to the spread of the pandemic into even remote villages (Bhutta et al., 2021). As mentioned earlier, political mass gathering (happening at proximity/extensive physical contact) for elections in different states has also lasted for over a month and due to frequent traveling of the political leaders to different states, the incident of COVID-19 has risen exponentially.

The complex nature of SARS-CoV-2 and the multitude of symptoms mentioned in a plethora of studies that report possible transmission routes in various environmental mediums (Kumar et al., 2020; Shao et al., 2021; de Oliveira et al., 2021). While some like air (aerosols, secretions, respiratory droplets), biota (minks, bats, pangolins), and fomites, as well as surfaces (food transportation, medical treatment, social gatherings), could be proven with little doubt (Shao et al., 2021), others like contaminated soil and water (via fecal-oral transmission) are more elusive but should not be ignored (Maal-Bared et al., 2020). Different clinical symptoms (lungs/intestine/eye infection) have been reported with the various primary and secondary transmission routes (respiratory, ocular, nasal, fecal-oral, blood vessels/lymphatic/hematogenous) of SARS-CoV-2 (Falahi and Kenarkoohi, 2020; Li et al., 2020). The vertical/transfusion transmission of SARS-CoV-2 has been contradictorily reported in the literature and flow physics of such disease transmission routes have been discussed thoroughly through the Susceptible-Exposed-Infectious-Recovered-Deceased (SEIRD) model (Chaudhuri et al., 2020; Falahi and Kenarkoohi, 2020). Although the airborne transmission of such highly transmissible etiological agents has been considered as the primary pathway of the pandemic outbreak, the

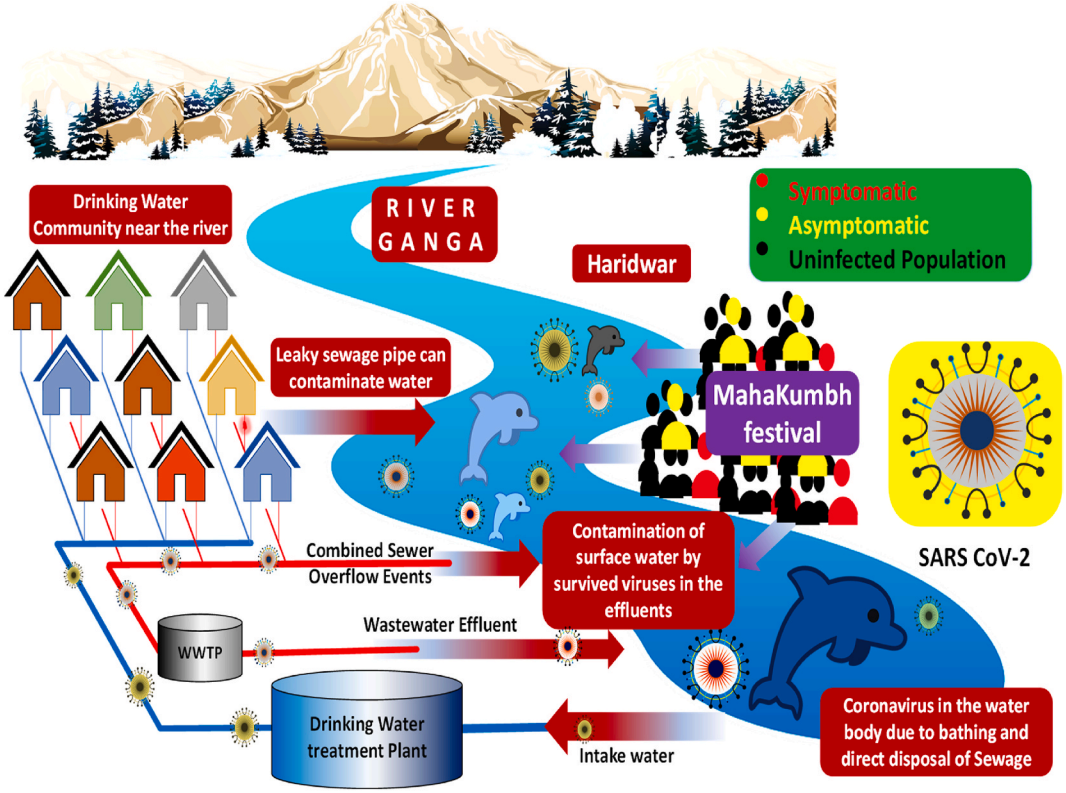

Fig. 1. Conceptual formulation of probable transmission of SARS-CoV-2 through the River Ganga during the Mahakumbh festival held at Haridwar.

waterborne transmission of these viruses should not be ruled out. Recent studies such as the one by de Oliveira et al. (2021) have documented the possible fecal-oral transmission and survival potential of SARS-CoV-2 in the water cycle, where such RNA viruses have been detected in untreated sewage/wastewater and agricultural run-off. Li et al. (2020) and Guo et al. (2021) have documented the association of gastrointestinal/enteric symptoms (through the infection of enterocyte lineage cells) for many other respiratory viruses although the fecal-oral transmission contributed a small proportion (≤20%) of respiratory virus transmission. Some researchers have reported the persistence of novel coronavirus in such a dissemination medium (untreated wastewater/fecal contamination) between 8 (≥35 °C) −27 days (≥4 °C) (Shao et al., 2021; Guo et al., 2021; Giacobbo et al., 2021). Although there is scanty information related to possible ways of virus migration through water sources, a group of the researcher through comparative genome analysis focused on the reverse zoonotic transmission of SARS-CoV-2 infection on aquatic vertebrates (Akinsorotan et al., 2021; Audino et al., 2021; Khan et al., 2020). Zhang et al. (2020) have reported that fecally contaminated water (stemming from wastewater discharges) can not be excluded as contributing to infections in the aquatic biodiversity of Ganga as SARS-CoV-2 can be detected with molecular methods targeting its RNA genome in fecal samples after an estimated 22 days compared to 16 days and 18 days in serum and respiratory specimens. To have a clear insight on viral occurrence and persistence in aquatic and marine ecosystems (and to study their possible negative impact?), it is of utmost importance to provide emphasis on the immunohistochemistry of sea mammals (Audino et al., 2021; Tiwari et al., 2020). Recently, wastewater surveillance has been globally recognized for tracking several emerging contaminants, the pattern of antibiotic use, and providing a weak signal of virus transmission at a community scale (Thompson et al., 2020). This approach of detecting the RNA of viral pathogens could also be exploited at the national level as a useful monitoring tool in early detection (and prevalence) of local clusters and outbreaks as well as asymptomatic carriers of SARS-CoV-2 in India, where a huge population and lack of resources often lead to under-detected cases (Kumar et al., 2020).

In addition to the individual-to-individual transmission of SARS-CoV-2, the MahaKumbh festival very likely resulted in contamination of the river Ganga by mucosal, intestinal, fecal, and skin microbes and thus increase bacterial loads during such holy dip, as recently reported by Upadhyay et al. (2021). Therefore, the potential risk of transmission of the infection to the aquatic environment from a variety of water-related diseases vectors (etiological agents causing, among others, typhoid, dysentery, and cholera) should not be ignored. In addition to the consensus that human, environmental, and animal health should not be viewed separately but as a whole (the “One Health” concept) (Yasobant et al., 2019), the existence of SARS-CoV-2 in cetaceans (whales and dolphins) raised a further dimension of the ongoing pandemic (Mathavarajah et al., 2021; Tiwari et al., 2020). COVID-19 infections of marine mammals have been confirmed through structural analysis of the protein sequences of the Angiotensin-converting enzyme 2 receptors (ACE2), the main point of attack of the SARS-CoV-2 spike protein (Damas et al., 2020; Delahay et al., 2021). Although there is not enough evidence in Indian perspectives to suggest the threat to aquatic biodiversity because of SARS-CoV-2, several epidemiologists/marine researchers have identified that captive marine mammals (such as cetaceans, fissipeds, and pinnipeds) could get infected with SARS CoV-2 through wastewater (Delahay et al., 2021; Guo et al., 2021; Mathavarajah et al., 2021). They have hypothesized that the social behavior of marine mammals, the transmission of the virus to mucous membranes from wastewater discharge sites (from fecal shedding), and close contact with asymptomatically infected caretakers may induce the risk of infection through water (Larsen and Wigginton, 2020; Khan et al., 2020). The South Asian River dolphins (*Platanista gangetica*) are regarded as the national aquatic animal of India, and wildlife experts have long warned about possible threats to their existence due to excessive water pollution, anthropogenic activities, and commercial water transportation services (Delahay et al., 2021; Paudel and Koprowski, 2020; Tiwari et al., 2020). According to the International Union for Conservation of Nature (IUCN), Gangetic river dolphins and Gharials (*Gavialis gangeticus*) were already listed under the “endangered” and “critically endangered” categories before the COVID-19 pandemic (Sinha et al., 2014). As several studies have reported the occurrence of SARS-CoV-2 in pets (dogs and cats) and wildlife (lions and tigers), the possibility of COVID-19 infections to aquatic mammals through horizontal (interspecies) and vertical (mammary gland infection/bodily fluids) transmission pathways (US-CDC, 2021) as observed in the case of Cetacean morbillivirus (CeMV) infections seem realistic (Jo et al., 2018; Quadri and Padala, 2021; Usui et al., 2021). Guo et al. (2021) have reported the impact of SARS-CoV-2 on marine animals through analysis of the biophysical hydrodynamic model and justified that in winter due to long persistence and long-distance migration there is a high chance of pathogenic contamination. Audino et al. (2021) and Charlie-Silva et al. (2021) have supported the hypothesis of potential susceptibility of different aquatic animals infection by SARS-CoV-2 through binding strength analysis of ACE-2 receptor and evaluation of biomarkers (synthesized SARS-CoV-2 spike protein peptides). Thus, after the MahaKumbh festival, the contaminated water from the ceremonial sites may prove even more detrimental to the Dolphin population than before. Hence, there is a significant potential threat to the Ganga’s aquatic biodiversity and fishing industries due to the presence of functional SARS-CoV-2 receptors in them.

Keeping in mind the public health risks and possible significant threats to aquatic (and marine) ecosystems it is advisable to avoid public interaction with fragile aquatic environments such as the river Ganga during this pandemic and that proper healthcare measures need to be addressed as early as possible before facilitating large (e.g. religious) gatherings along its shores shortly. However, the matter of food chain contamination is yet untouched by the concerned research community. The issue draws inevitable importance since marine species as well as a human population are involved in the food chain, it’s high time to invest attention to study this aspect. To minimize the possibility of a health crisis during such religious gatherings, some socio-administrative measures (i.e. online registration and GPS tracking) of pilgrims/participants, the screening of most susceptible (i.e. older and sick) people in gatherings, the scaling up of healthcare infrastructure, adhering to non-pharmaceutical measures such as face masks, hand hygiene and social distancing (where possible) as well as promoting advanced public health facilities after meeting with organizing committee and religious leaders can be adopted. Additionally, some other preventive measures i.e. the infrastructure of hand-sanitizing stations, clean and hygienic quarantine facilities, utilizing the concept of “Digital India” (digital infographics) before and during the festival, should be recommended and included in planning to obviate complex public health challenges. However, it is of utmost importance to build up a multi-disciplinary consortium of event managers, administrators, public health experts, and academics (at national and international levels) to draft and design robust recommendations and clear guidelines. This will also provide context-specific solutions so that improved policies and practices can be implemented to mitigate the potential risk factors during congregated events such as the MahaKumbh festival, the Hajj etc., and any other religious gatherings of such scale globally. Such interdisciplinary approaches based on evidence-based efficient learning, contextual strategies, and a streamlined, unified approach will help develop a proactive prevention model during such religious mass congregation instead of a conventional post-event model.

Declaration of competing interest

The authors declare no competing financial interest.

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