EDITORIAL

TITLE: Climate change, cyclones and cholera - implications for travel medicine and infectious diseases

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Cholera, although largely underreported, is thought to be responsible for around 3 million diarrheal cases and an estimated 100,000 deaths in 69 endemic countries, predominantly in sub-Saharan Africa and Asia (1, 2). Cholera causes acute diarrheal episodes which result from the ingestion of the enterotoxin producing *Vibrio cholerae,* a highly motile, flagellated Gram-negative rod that exists in aquatic environments, like coastal waters and estuaries (3). There are more than 200 serogroups based on the O antigen of its membrane's lipopolysaccharide. Only two serogroups cause epidemic cholera: O1 and O139. Since *Vibrio Cholerae* was first isolated by Koch more than 160 years ago, there have been several epidemics, mainly caused by serogroup O1 which may be divided into two biotypes: classical and El Tor. The latter is responsible for the current seventh pandemic and has substituted the classical biotype which is supposed to have caused the previous pandemics (3). Each biotype is classified in three serotypes: Inaba, Ogawa (the most prevalent) and Hijokima (more rare).

Vibrio cholerae is transmitted by ingestion of contaminated water or food (rice products, raw vegetables, fruits or shellfish), direct fecal oral contamination or person-to-person transmission (3). Clinically, mild cholera may be identical to other diarrheal illnesses but the presentation is distinct when it manifests as severe cholera. This is characterized by a painless, abundant, non-bloody, secretory diarrhea ('rice water'), normally accompanied by nausea and vomiting which can have a high associated (>50%) mortality due to dehydration in the first hours after its sudden onset (4). Children under five years of age and those patients with immunity disorders are highly vulnerable populations. Travelers usually have a lower risk of infection (4). If well treated with aggressive fluid replacement and effective antibiotic therapy, mortality may decrease to less than 0.5% (3).

Natural disasters are defined by the World Health Organization as "*catastrophic events with atmospheric, geologic and hydrologic origins*" (5). Since the second half of the 20th century there has been an increase in the occurrence of natural disasters globally, with around 270 million people being affected annually. Such natural disasters occur mainly in developing countries which are the areas disproportionally bearing the brunt of the problem, mainly as a result of the lack of specific containment and protective resources (6). These natural disasters

include exposure to extreme temperatures, wildfires, droughts, volcanic eruptions, earthquakes, tsunamis, floods, as well as tropical cyclones (6), which are also known as hurricanes and typhoons depending on the wind speed and the geographic location (7). Cyclones periodically impact human populations and produce devastating effects as a consequence of their destructive forces: cyclonic winds, rains, storm surges, floods, tornadoes, or landslides (7).

Tropical cyclones are poorly understood weather phenomena in comparison to other climate events, and large differences again emerge in the capacities available so far to predict them in the different ocean basins. This is further enhanced by the larger uncertainties arising in the Indian Ocean, due to poorer coverage of the observational record and a complex, poorly-understood, regional ocean dynamics. Recent predictions of the Indian summer monsoon failed for instance, in 2018, to predict larger-than-expected torrential rainfall, flooding and landslides occurring over Kerala. In such scenario, it is clear that accurate predictions of geolocation of areas affected by tropical cyclones in the Indian Ocean basin are still far from reality. Very recently, a new study(8) showed also the sea level in the Indian Ocean rises and falls every 30 to 80 days in an ocean-atmosphere swing related to the Madden-Julian Oscillation (MJO). The MJO, as a low-pressure system, has great implications for the forecasting of cyclonic storms for it facilitates cyclone formation over the Indian Ocean with implications for the intensely-populated coasts. It is also difficult to have full consensus on whether climate change is exacerbating hurricane intensity, as most studies only covered a few events and although model simulations are uncertain, a clear trend seems to be emerging that points to continuous warming in the ocean and atmosphere cancelling any counteracting effect of aerosol cooling(9).

By modifying the geographical landscape, and with this the ecology of pathogens, natural disasters may increase the risk of proliferation of infections and exposure to diseases (6). After Hurricane Mitch lashed Central America there was an increase in cases of cholera in countries like Guatemala, Nicaragua and Belize (10). In the same line, there were two cholera outbreaks in West Bengal, India in 2009 (11) and in Pondicherry, India, in 2012 (12) in the aftermath of two tropical cyclones. In these cases of tropical cyclones the increase of diarrhea and other infectious diseases could be explained due to the destruction of water and sanitation structures and pools of stagnant water with subsequent consumption of contaminated drinking water (13).These results

are compatible with the increase of diarrheal cases observed in Guandong province, affected by different cyclones during a period of six years, although cholera was not specifically studied (14). More recently, a cholera outbreak has been declared in Mozambique, after Ciclone Ibay affected the central region of the country.

In the period immediately after a tropical cyclone the risk of cholera and infectious diseases is low but it seems to progressively increase associated with its prolonged after-effects (6). This situation is particularly true in developing countries (especially those areas with ongoing conflicts) where the interaction between disrupted or destroyed health resources (in the context of pre-existing fragile health systems), damage of water and sanitation infrastructures, poor access to clean water sources, lack of effective hygiene practices, displacement and resettlement of people and increased susceptibility of human to pathogens may have catastrophic consequences (6).

There are different statistical and geo-spatial methods in development to obtain better hydroclimatological data of those regions affected by natural disasters (6). Those data and the continuous gain in the understanding of cholera epidemiology provided by dynamical models developed in different epidemic settings(15), will definitely help in the future to improve the predictability of cholera outbreaks and the response to its impact. Such model may also help to develop “preparedness”. This could include the organization of response vaccination campaigns, such as the current one in-place in Mozambique. Alternatively, vaccination campaigns targeting high-risk groups preceding the cyclone season in areas where these phenomena are frequent may be an interesting approach to consider.

Travelers must be aware of the complex sanitarian situation of regions affected by a tropical cyclone and follow general preventive recommendations (4). To minimize the risk of infection, travelers are advised to follow basic hygiene recommendations, specially hand hygiene and to avoid consumption of untreated water or raw or undercooked food (4). Preventive antibiotic chemoprophylaxis for travelers is not recommended but carriage of oral rehydration can be advised, in addition to water purification devices. Cholera vaccination is only recommended for specific travelers (emergency/humanitarian workers; long term visitors) who

will be in direct contact with cholera patients, exposed to contaminated food or water and without proper access to health care facilities (4).

Authors' contribution

RV wrote the first draft of the manuscript, together with QB. RV, QB and XR critically revised the manuscript. All authors approved the final manuscript

Conflict of interests

The authors declare that they have nothing to disclose.

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