Hydrology–climate–human health: a hydroclimatological approach to understand cholera transmission in South Asia and sub-Saharan Africa

ALI S. AKANDA[1], ANTARPREET S. JUTLA[1] & SHAFIQUL ISLAM[1,2]

1 *WE REASoN (Water and Environmental Research, Education, & Actionable Solutions Network), Department of Civil and Environmental Engineering, Tufts University, Medford, Massachusetts, USA*
ali.akanda@tufts.edu

2 *Water Diplomacy, The Fletcher School of Law and Diplomacy, Tufts University, Massachusetts, USA*

Cholera broke out in the form of global pandemics from the Bengal Delta region of the Indian Subcontinent in the early 19th century. Two hundred years later, the disease still remains a major threat to public health in many developing countries around the world, especially in South Asia, sub-Saharan Africa, and Latin America. Despite major advances in the understanding of the micro-environmental conditions (ecological and micro-biological) of the cholera bacterium (Colwell, 2006), the role of the macro-environmental conditions, such as seasonality of this infectious disease and annual recurrence in endemic areas, remain a mystery (Jutla *et al.*, 2010). Recent findings underscore the role of the regional hydroclimatic extremes such as droughts and floods on cholera outbreaks in South Asia (Akanda *et al.*, 2009). However, the role of large-scale hydroclimatic processes and the impact of varying climate patterns affecting cholera dynamics in the 21st century is not well understood. The interaction between the complex micro-environment of this water-borne infectious disease, the coastal nature of the primary outbreaks around the world, and the role of seasonal hydroclimatic controls make this a "wicked" water problem.

Our research focuses on understanding large scale macro-environmental processes that play a dominant role in the seasonal and interannual variability and the nature of the cholera transmission process. Cholera incidence in the Bengal Delta region, the native homeland of cholera, shows unique biannual peaks, as opposed to single annual peaks in other affected regions. Here, we show that the biannual cholera peaks are governed by two distinctly different, pre- and post-monsoon, hydroclimatic conditions. A coupled analysis of the regional hydroclimate and cholera incidence reveals strong association of the variability of incidence with seasonal streamflow patterns and extreme events such as droughts and floods (Fig. 1). This coupled seasonal investigation approach on the complex interactions between hydrology, climate, and the ecology of cholera provides us with a powerful tool to systemically identify the dominant processes and explain the spatio-temporal nature of the seasonal cholera transmission cycles in the Bengal Delta region.

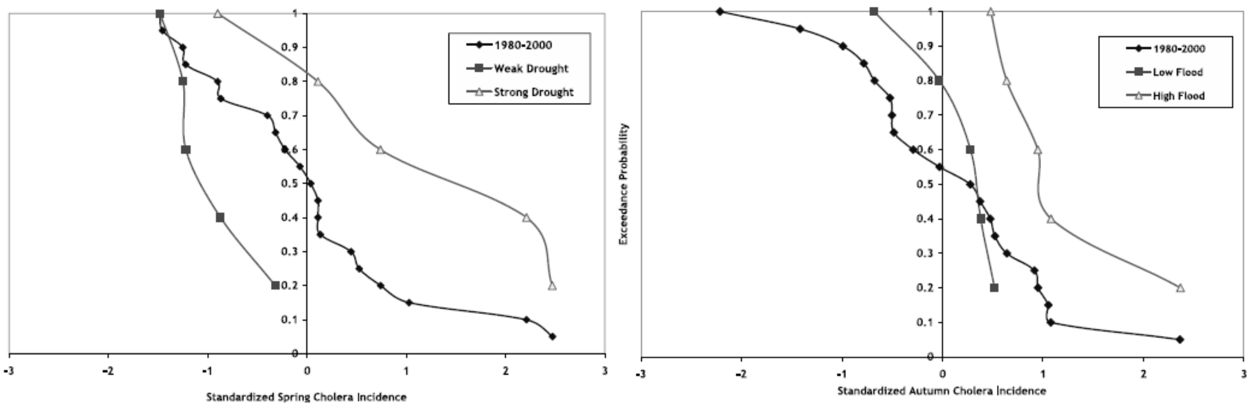

Fig. 1 Role of droughts and floods on seasonal cholera incidence.

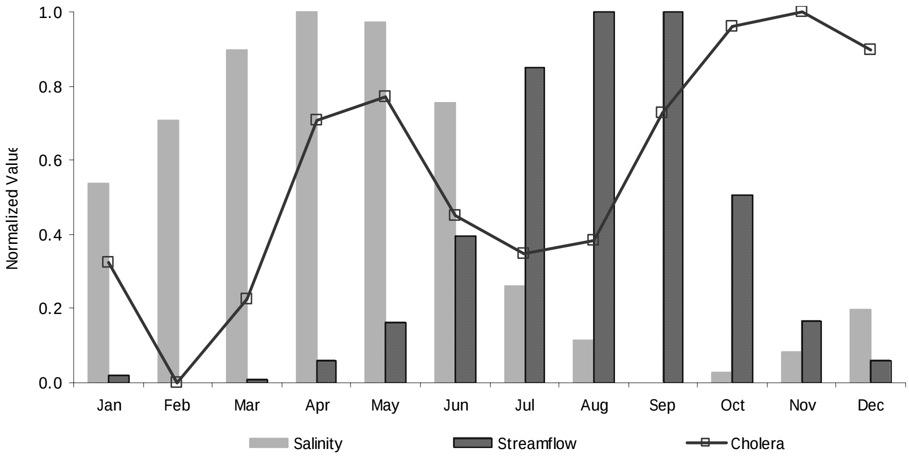

Fig. 2 Seasonal patterns of cholera incidence, streamflow and coastal salinity.

The hydroclimatology of the Bengal Delta region is highly asymmetric, with most of the annual precipitation occurring during the four monsoon months of June–September. Preliminary results show that estuarine rivers in the region provide an ideal growth environment for the bacteria as inward movement of plankton-rich seawater and increased salinity in coastal river corridors in the dry season favour abundance of the bacteria as the first cholera outbreaks are initiated in spring (Fig. 2). A distinctly different role of the rivers, however, dominates the cholera transmission process in summer and autumn. River channels, bulging with heavy monsoon rainfall, inundate the Ganges and Brahmaputra flood plains, and contaminate open and closed water networks with the bacteria already present in the ecosystem, leading to a breakdown in sanitation. These two contrasting large-scale hydroclimatic scenarios have been found to modulate seasonal and interannual variability of cholera incidence in various locations of the Bengal Delta region of South Asia, including the megacities of Dhaka and Kolkata.

Our understanding of the processes of regional hydroclimatic conditions and associated cholera transmission has considerable societal and policy relevance, as a quantitative understanding of the relationship(s) among seasonality of river flow, plankton blooms, sea-surface temperature and cholera outbreaks will make early cholera detection, a key for preventing an epidemic, possible. Our results may also serve as the basis for formulating effective cholera intervention and mitigation efforts through improved water management, and assessing the impacts of changing climate patterns on cholera transmission in South Asia and increasingly affected regions in sub-Saharan Africa. We are working closely with our partners in the USA and Bangladesh to integrate these findings into an operational cholera tracking system and produce *actionable knowledge* for health professionals in endemic regions to prepare for interventions in advance.

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