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Predicting the evolution of large cholera outbreaks: lessons learnt from the Haiti case study

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Mathematical models can provide key insights into the course of an ongoing epidemic, potentially aiding real-time emergency management in allocating health care resources and possibly anticipating the impact of alternative interventions. Spatially explicit models of waterborne disease are made routinely possible by widespread data mapping of hydrology, road network, population distribution, and sanitation. Here, we study the ex-post reliability of predictions of the ongoing Haiti cholera outbreak. Our model consists of a set of dynamical equations (SIR-like, i.e. subdivided into the compartments of Susceptible, Infected and Recovered individuals) describing a connected network of human communities where the infection results from the exposure to excess concentrations of pathogens in the water, which are, in turn, driven by hydrologic transport through waterways and by mobility of susceptible and infected individuals. Following the evidence of a clear correlation between rainfall events and cholera resurgence, we test a new mechanism explicitly accounting for rainfall as a driver of enhanced disease transmission by washout of open-air defecation sites or cesspool overflows. A general model for Haitian epidemic cholera and the related uncertainty is thus proposed and applied to the dataset of reported cases now available. The model allows us to draw predictions on longer-term epidemic cholera in Haiti from multi-season Monte Carlo runs, carried out up to January 2014 by using a multivariate Poisson rainfall generator, with parameters varying in space and time. Lessons learned and open issues are discussed and placed in perspective. We conclude that, despite differences in methods that can be tested through model-guided field validation, mathematical modeling of large-scale outbreaks emerges as an essential component of future cholera epidemic control.