The Village Zero Project

Ghost-mapping endemic cholera in Bangladesh

Every year, 3–5 million individuals contract cholera, an acute diarrheal infection caused by the ingestion of food or water that contains the *Vibrio cholerae* bacteria. Because cholera is a waterborne disease, it can be transmitted quickly in environments where infected waste easily pollutes the drinking water due to inadequate sewage and sanitation systems. The bacterium originates in brackish seawater; as a result, cholera is endemic in many coastal, developing countries. Observations suggest that most cholera outbreaks begin in coastal areas and progress inland. However, this geospatial progression has yet to be demonstrated empirically. The Village Zero Project (V0P) aims to map and verify this progression, such that geographically targeted cholera control stratagems can be implemented in the most susceptible coastal communities—thus stopping endemic outbreaks before they can spread. Such geographic targeting would allow resource-limited, cholera-endemic countries to use the fewest available resources for the greatest possible reduction in cholera.

Theoretically, two seasonally correlated, temporally predictable outbreaks of cholera occur in Bangladesh every year. In the spring, the Bay of Bengal—which serves as a natural reservoir for the cholera bacteria—experiences a tidal influx, observably causing the first outbreak among coastal communities. Waste containing the cholera bacteria enters the sewage system and remains untreated due to poor water and sanitation infrastructure. Therefore, during the late summer monsoon season, flooding of cholera-contaminated sewage into drinking water sources results in a second outbreak.

WATER IMAGE©KPT POWER PHOTOS

In order to empirically demonstrate where outbreaks originate and how they proliferate, V0P has designed an endemic disease-mapping schematic for cholera in Bangladesh and other developing countries. We have coined this schematic as "ghost-mapping": the mapping of an endemic disease that is unseen and unheard but is a chronic threat to livelihood. Ghost-mapping will enable us to accurately identify the index region from which the spring outbreak initiates. Resources can then be redistributed to this area, ultimately reducing annual disease incidence via preemptive prevention (i.e., geographically targeted improvements in infrastructure).

To most effectively implement ghost-mapping in a developing country like Bangladesh, creative and affordable resources must be utilized. Because of Bangladesh's prominent not-for-profit community, trusted non-governmental organizations like the International Centre of Diarrheal Disease Research, Bangladesh (ICDDRB) have been able to collect monthly cholera incidence data through their free clinics and surveillance regions in both urban and rural Bangladeshi populations. Furthermore, monthly climate data for Bangladesh can be derived from public satellite imagery databases such as the U.S. Geological Survey Global Visualization Viewer (GloVis). Such climate data—namely variables such as rainfall and temperature, which dictate spring season tidal influx and summer monsoon flooding—can be correlated with cholera incidence data for any given month at any of ICDDRB's data-collecting locations. We hypothesize that communities

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along the coast will experience highest cholera incidence when climatic variables are most suitable for tidal influx, whereas inland communities will experience highest incidence when the climate is most susceptible to monsoon flooding. V0P believes that ICDDRB and GloVis can provide the initial data necessary to develop a data visualization that characterizes the macroscale transmission of cholera with respect to climate, time, and space.

To complement the aforementioned static datasets, mobile health (mHealth), which uses mobile technologies for health surveillance, is a particularly promising tool for dynamic ghost-mapping. As demonstrated by previous studies across Africa and in Haiti, mHealth has the potential to remotely diagnose cases of cholera and plot disease outbreaks geospatially. As such, mHealth technologies can also be used for the ghost-mapping of endemic cholera in Bangladesh, better informing the climatic, temporal, and spatial parameters of the initial data visualization.

Data collection and processing, which will begin in Summer 2012, will take place in five to ten communities that are evenly distributed across the coast and immediately inland. This first phase of data collection will consider disease incidence and climate records from the ICDDRB and GloVis, respectively. One of our communities will be a subset of villages in Matlab, which is a rural upazila immediately north of the coast and is under the health care jurisdiction of the ICDDRB. The ICDDRB—with whom we have an established working partnership—has provided V0P with access to ten years of cholera incidence data in this community and guidance in data management and analysis. To ensure that an urban population is also represented, we plan to use a subsection of Chittagong, an eastern seaport city that is under health surveillance by the ICDDRB. Additional communities that rely primarily on traditional and local medicinal providers for health care will also be included in order to be representative of all common health cultures.

Like any reputable research, several phases of data collection must take place before a substantive visualization can be produced. To supplement our findings from Summer 2012, we anticipate returning to Bangladesh in Spring 2013 to collect data in a total of 25+ communities. In this second phase, we will use disease incidence and climate data, as well as mHealth data collection, to refine the visualization.

Water and sanitation infrastructure interventions can be implemented in the most disease-prone regions, thus stopping future endemic outbreaks before they spread.

To collect both temporal and spatial cholera case data via mHealth technology in Spring 2013, V0P plans to use Android-operated cellular phones. National mobile coverage and affordability of basic Android-operated devices ensures feasibility of such an approach. In order to acquire cellular phones and network support, we will appeal to GrameenPhone—a Bangladesh-based mobile service provider with a demonstrated history of corporate social responsibility—to serve as a potential partner. To design the data collection software, we are using a mobile platform called Open Data Kit (ODK). ODK is an open-source platform that allows users to create, deploy, and manage a wide variety of mobile data collection initiatives. ODK will enable us to handcraft mobile device software that will allow us to acquire global positioning system (GPS) coordinates, date/time stamps, and diagnostic and demographic information. However, V0P predicts that an initial visualization of cholera propagation through Bangladesh can be produced from the data collected and processed in Summer 2012.

Additionally, we expect to lay the groundwork necessary for subsequent data collection by constructing concrete partnerships with Bangladeshi health and technology organizations in Summer 2012. In an infrastructure-weak country like Bangladesh, such partnerships are critical to V0P's sustainability and long-term success. Government-endorsed community health centers; well-respected local research hospitals; and Dutch and Danish water, sanitation, and health organizations are already in active operation throughout Bangladesh. We intend to establish relationships with such entities during Summer 2012 and hope to contract the majority of the health workers needed for second-phase data collection from this existing infrastructure.

In Spring 2013, health workers will be assigned to the 25+ selected communities in which they will be responsible for monitoring diarrheal disease outbreaks. Mobile phones preloaded with ODK-based data collection software will be distributed to health workers, who will then be trained to monitor cholera using the software. To reliably confirm cases of cholera, health workers will conduct diagnostic dipstick tests on the diarrheal stool samples. Positive dipstick tests will be photographed, and relevant demographic data—including number of symptomatic household members, date of onset, and location—will be submitted to the case database. Using this protocol, V0P will use the case data that amasses to enhance the temporal and spatial parameters of the cholera propagation visualization.

As the nation's most prevalent diarrheal disease, upwards of 1 million people contract cholera in Bangladesh every year. Such a disease burden results in incalculable lost wages and treatment expenses taken from the pockets of an already impoverished society. In this way, cholera fuels the economic and social instability faced by this politically unstable nation. Through ghost-mapping, V0P will find the index region from which cholera originates and understand how it proliferates. With this knowledge, water and sanitation infrastructure interventions can be implemented in the most disease-prone

regions, thus stopping future endemic outbreaks before they spread.

If successful in Bangladesh, ghost-mapping has the potential to help cholera-endemic countries worldwide use their limited resources for the greatest possible reduction in disease burden. By deriving the information necessary to significantly reduce endemic cholera incidence, the V0P will do its best to empower citizens of the developing world by returning to them an essential asset: the health they need to improve their quality of life.

The three core members of V0P are Tufts University undergraduates:

- *David Meyers: technical expert and mHealth specialist*
  David is a junior double majoring in international relations and community health. During his time as vice president of Engineers Without Borders, he helped implement a new water system in a village in rural Uganda. Furthermore, he has explored the use of mHealth technologies in Central America and Africa during research trips abroad. His primary research interests include infectious disease outbreaks in developing countries and the growing utility of mHealth technology, which have been of significant value to V0P.
- *Katharina (Kate) de Klerk: head of finance and public relations*
  Kate is a premed senior majoring in international relations with a concentration in global health. Her expertise focuses on the use of partnerships between the private sector, governments, nongovernmental organizations, and the United Nations in implementing sustainable solutions for complex social issues, specifically those affecting the health of populations. She has performed medical and clinical work in The Gambia and has also interned at the UN Office for Partnerships. Her passion for public health and her understanding of partnerships have been crucial to V0P.
- *Maimuna (Maia) Majumder: executive director and cultural liaison*
  Maia is a senior majoring in engineering science and will also be receiving her M.P.H. in 2013 in epidemiology and biostatistics via Tufts' five-year bachelor's/M.P.H program. Her independent research is in cholera prevention in Bangladesh, with a particular focus on interventions via innovative and implementable improvements in infrastructure. She began her research correspondence with the International Centre of Diarrheal Disease Research, Bangladesh, in 2009. Currently, she is drafting several journal articles regarding the most effective infrastructural intervention points for cholera in Bangladesh. As a native Bengali speaker with a strong, current presence in the Bangladeshi public health community, her cultural and professional background is essential to V0P.

Maimuna Majumder

—Maimuna Majumder, Katharina de Klerk, and David Meyers

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